Systematic Review Article

Activation and installation of orthodontic appliances temporarily impairs mastication: *A systematic review with meta-analysis*

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ABSTRACT

Objectives: To investigate the masticatory (masticatory performance, bite force, swallowing threshold, muscle activity, and questionnaires) and nutritional (nutrient intake) impacts of the activation and/or installation of different orthodontic appliances (fixed labial, lingual appliances, and clear aligners).

Materials and Methods: Six electronic databases and gray literature were searched (up to May 2021) for relevant studies evaluating mastication and nutrition after activation/installation of orthodontic appliances. This review followed PRISMA guidelines and was registered at PROSPERO (CRD42020199510). The risk of bias (RoB 2 and ROBINS-I) and evidence quality Grading of Recommendations Assessment, Development, and Evaluation were analyzed.

Results: Of 4226 recorded and screened, 15 studies were finally included. Masticatory performance (standardized mean difference [SMD]: 1.069; 95% coefficient interval [CI]: 0.619 to 1.518) and bite force (SMD: -2.542; 95% CI: –4.867 to –0.217) reduced in the first 24 to 48 hours of fixed labial appliance installation/activation, but they were both normalized after 30 days ($P > .05$). The swallowing threshold remained constant ($P > .05$). Nutritional intake was rarely reported but showed copper ($P = .002$) and manganese ($P = .016$) reductions, with higher calorie and fat intake ($P < .05$). Lingual appliances impacted chewing more than labial, and clear aligner wearers reported fewer chewing problems ($P < .001$). Low to very low levels of evidence were found.

Conclusions: Based on low to very low levels of evidence, mastication was reduced during the first 24 to 48 hours of fixed labial appliance activation/installation, but it was transitory (up to 30 days). Due to insufficient data, the nutritional impact of orthodontic appliances was not conclusive. (*Angle Orthod.* 2022;92:275–286.)

KEY WORDS: Fixed orthodontic appliances; Clear aligners; Mastication; Nutrition assessment; Systematic review

INTRODUCTION

Orthodontic tooth movement depends on the applied force and the biological response from surrounding tissues.[1,2] Tension and compression forces change periodontal blood flow, resulting in a local inflammatory process that provides a favorable microenvironment for alveolar bone deposition or resorption, ultimately resulting in tooth movement.[1] Frequently, this acute inflammatory process is associated with painful sensations and discomfort,[2,3] and some patients avoid

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chewing hard and consistent food, adopting a soft diet as described in previous treatment studies.[4]

Different orthodontic modalities are now available beside conventional fixed labial appliances, including lingual appliances and clear aligners. However, little evidence exists on how each orthodontic treatment would affect mastication.[3,4] A recent review[5] reported that patients using fixed lingual appliances would be more likely to suffer from eating difficulty than those with labial appliances. In contrast, patients using clear aligners reported fewer chewing limitations than those using fixed labial devices.[6] With increasing interest in esthetic and digitally guided dental procedures such as clear aligners, it is important to evaluate the functional impact of these new treatment modalities.

Orthodontic patients also reported taste changes and that it took a longer time for eating.[7] Chewing difficulties may be caused by orthodontist advice to avoid certain foods, fear of breakage, and even social embarrassment.[7] Taken together, these factors may contribute to food restrictions and lead to nutritional problems. However, studies evaluating nutritional changes during orthodontic treatment are scarce and, to date, the reliability of this evidence has not been critically assessed. Therefore, this systematic review aimed to investigate the masticatory and nutritional impact of the installation and/or activation of different orthodontic appliances (fixed labial and lingual appliances, and clear aligners) to answer the focused question: "How does the activation and/or installation of different orthodontic appliances affect the masticatory function and nutrition of patients?"

MATERIALS AND METHODS

Protocol and Registration

This systematic review was reported according to updated PRISMA guidelines.[8] The study protocol was registered at PROSPERO under the registration number CRD42020199510.

Eligibility Criteria

The PICO (Patient/Problem, Intervention, Comparison, Outcome) strategy was applied. Randomized and non-randomized controlled clinical trials, as well as before and after studies, performed in adults and adolescents (P), undergoing different orthodontic treatments (I) comparing the mastication and nutrition (O) between baseline and a period after the activation or installation of appliances were selected. Studies reporting data from partially edentulous patients, case series, animal models, reviews, and noncontrolled studies were excluded.

Information Sources and Search

Searches in the following databases started in August 2020 with the last update performed in May 2021: Cochrane Library, EMBASE, Latin American and Caribbean Health Sciences (LILACS), PubMed (including Medline), SCOPUS, and Web of Science (Supplemental Table 1). Gray literature was also searched (Google Scholar, Open Grey, and ProQuest). A hand search on the reference lists of included studies was also performed (Figure 1). No language, publication time, or follow-up period restrictions were applied. The reference manager EndNote (version X9, Clarivate, Philadelphia, PA, USA) collected references and removed duplicates.

The study selection was independently conducted in a two-phase process. In phase one, titles and abstracts that did not fulfill eligibility criteria were excluded. In phase two, full texts of the remaining studies were evaluated (Supplemental Table 2). The entire process was conducted by two calibrated authors (LD and APB) using Rayyan.[9] Any disagreement was solved with the coordinator (TMSVG).

Data Extraction and Risk of Bias

Two independent reviewers (LD and APB) performed data extraction using spreadsheets (Excel v.16.49, Microsoft, Redmond, WA, USA). The authors, year of publication, study design, country, sample size, gender, age of participants, type of orthodontic appliance, follow-up time, and outcomes were obtained from the included studies (Table 1). To retrieve any pertinent unreported information, the authors made up to three attempts to contact corresponding authors. For mastication assessment, the masticatory performance, bite force, swallowing threshold, and masticatory muscle activity were considered as main outcomes; whereas, for the nutritional assessment, the nutrient intake, risk of malnutrition, blood nutrient levels, and body mass index were the main outcomes considered in the analysis.

The risk of bias was independently analyzed by two reviewers (APB and LJP). The coordinator (TMSVG) was involved in solving disagreements. To evaluate the risk of bias of the randomized controlled trials (RCTs), the revised Cochrane Collaboration tools RoB 2[10] were applied. The Intervention tool ROBINS-I[11] for non-randomized studies, specifically considering the before and after design, was applied in the remaining studies. For each domain, the risk of bias was judged as "low risk," "unclear risk," and "high risk."[12] The Risk-of-bias VISualization (robvis) tool was used to summarize data.

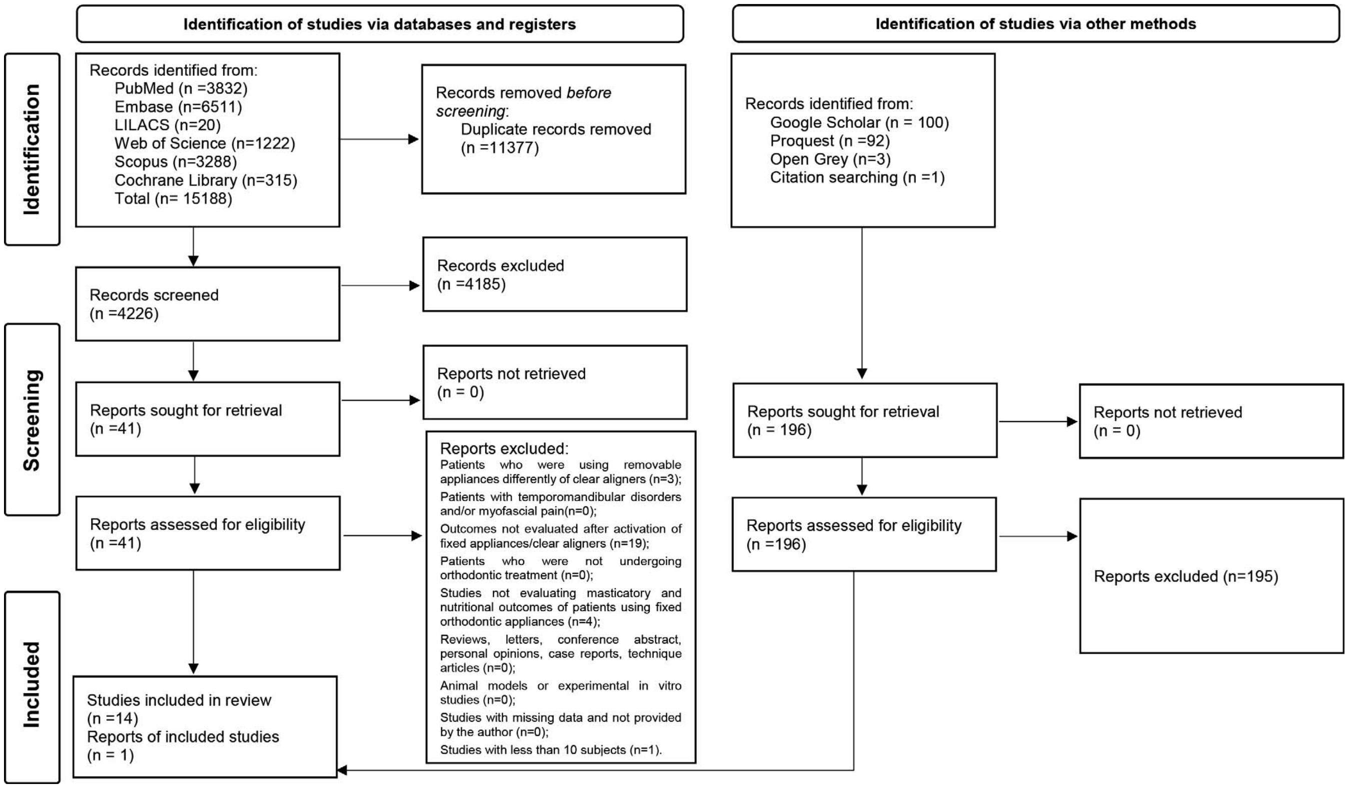


Figure 1. Flowchart of the selection process (PRISMA 2020).

Level of Evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) criteria was used to assess the overall quality of the evidence. In addition, included studies were evaluated by two independent reviewers (APB and LJP) according to their design, study quality, consistency, directness, and publication bias.[13] As a result, the overall quality of the evidence was categorized as high, moderate, low, and very low (Table 2).

Statistical Analysis

Outcomes from studies with similar methodologies and follow-up times were pooled for statistical analysis (Supplemental Table 3). Repeated-measure comparisons between pre/post assessments on masticatory performance, swallowing threshold, bite force, and pain were performed with Comprehensive Meta-Analysis software (v.3, Biostat Inc., Englewood, NJ, USA). A median correlation of 0.5 was adopted for all comparisons. The standardized mean difference (SMD) and 95% coefficient interval (CI) were estimated using a random-effects model and transformed to draw forest plots. Statistical heterogeneity was assessed with I-square statistics. The significance level was set at 5%.

RESULTS

Selection and Characteristics of Included Studies

A total of 15,188 citations were retrieved from electronic databases. After duplicate removal, 4226 title/abstract articles were evaluated. An additional 196 records were identified through gray literature and hand searching. After phase one, 41 articles were selected for full-text analysis and 27 articles were excluded based on eligibility criteria (Supplemental Table 2). In the end, 15 studies were included ($k = .89$ for phase 1 and $k = .81$ for phase 2). The search details are illustrated in the PRISMA flowchart (Figure 1).

Characteristics of the included studies are summarized in Table 1. All studies were published between 1994 and 2020, and a total of 480 patients, ranging from 11 to 35 years old (mean: 21.7 years old) were included. Fixed labial appliances were bonded in 341 patients, while 70 individuals used clear aligners and 69 received lingual appliances. Nine studies[3,4,14–20] investigated outcomes exclusively of fixed labial appliances. Two studies compared labial to lingual appliances,[21,22] while another two articles compared labial appliances to clear aligners.[6,23] The remaining two studies reported outcomes only from clear aligners[24] or fixed lingual appliances.[25]

Table 1. Main Characteristics of the Included Studies (n = 15)

Author, Year (Country)	Study Design	Experimental Groups (N)	Mean Age ± Standard Deviation (Years)	Follow-Up Time (Before and After Installation)	Mastication Outcomes	Nutrition Outcomes	Pain After Activation	Main Conclusions
Alomari et al., 2012[14] (Jordan)	Non-randomized clinical trial (before-after study)	Control (normal occlusion) (n = 47) Fixed labial appliance (n = 47)	19.0 ± 3.4	Baseline (T0) One week (T1) Two weeks (T2) 1–6 months (T3–T8)	Bite Force (N) 418.9 ± 135.8 (T0) 152.8 ± 109.5 (T1) 212.8 ± 114.3 (T2) 310.7 ± 142.1 (T3) 359.9 ± 135.6 (T4) 391.2 ± 129.3 (T5) 383.1 ± 135.5 (T6) 397.8 ± 126.8 (T7) 408.5 ± 123.8 (T8)	N/A	VAS (mm) 4.46 ± 2.67 (T1) 3.07 ± 2.46 (T2) 1.43 ± 1.91 (T3) 0.98 ± 1.60 (T4) 0.29 ± 1.12 (T5) 0.50 ± 1.24 (T6) 0.15 ± 0.70 (T7) 0.24 ± 0.82 (T8)	Bite force significantly reduces (50%) after the fixed labial appliance installation but, with the time, it returns to the pretreatment levels.
Alajmi et al., 2019[6] (Kuwait)	Non-randomized clinical trial (before-after study)	Clear Aligner (n = 30) Fixed labial appliance (n = 30)	Clear Aligner 32.9 ± 6.9 fixed labial appliance 23.6 ± 5.3	1 wk	Eating limitations (questionnaire) Clear Aligner 6 (20%) fixed labial appliance 23 (76.6%)	N/A	Likert-scale questionnaire Clear Aligner 5.4 ± 1.8 fixed labial appliance 5.4 ± 2	Clear aligner group reported more comfortable eating and chewing compared to fixed labial appliances, due to the fact that subjects with Invisalign have the ability to remove their appliance temporarily during meals. However, clear aligners affect pronunciation and speech delivery in the short term.
Gameiro et al., 2015[16] Silva Andrade et al., 2018[15] (Brazil)	Non-randomized clinical trial (before-after study)	Control (normal occlusion) (n = 15) Fixed labial appliance (n = 20)	18 ± 4	Baseline (T0) 24 h (T1) 1 mo (T2)	Masticatory Performance (X_{50}) 6.6 ± 2.2 (T0) 8.7 ± 2.0 (T1) 6.5 ± 1.8 (T2)	N/A	VAS (mm) 9.6 ± 16.7 (T0) 61.3 ± 32.8 (T1) 13.0 ± 22.3 (T2)	The masticatory performance of patients using fixed labial appliances is reduced at 24 h after arch wire placement and returned to basal levels after 1 mo but remains still lower than that of the controls.
Goldreich et al., 1994[17] (Israel)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 22) Placebo control (n = 22)	11–15 y	Baseline (T0) 48 h (T1)	EGM Masseter fixed labial < placebo Peanuts (t21 = 3.41, $P < .05$). Chewing gum (t19 = 3.89, $P < .05$). Swallowing threshold (number cycles) fixed labial > placebo (t20 = -1.77, $P < .04$)	N/A	VAS (mm) 0.29 ± 0.35 (T0) 4.92 ± 2.59 (T1)	Compared to a placebo, the activation of fixed labial appliance significantly decreased the masseter EMG activity while chewing. Orthodontic patients take more strokes to prepare the food but the size of the swallowed particles remains constant.
Hohoff et al., 2003[25] (Germany)	Non-randomized clinical trial (before-after study)	Fixed lingual appliance (n = 22)	34.7 ± 10.4	Baseline (T0) 24 h (T1) 3 mo (T2)	Chewing difficulties (questionnaire) T0 vs T1 ($P < .000$) T1 vs T2 ($P = .024$) T2 vs T0 ($P \leq .001$)	N/A	N/A	After placement of the fixed lingual appliance, the patients reported significantly more difficulty in chewing. These difficulties remain up to 3 mo before brackets placement.
Khattab et al., 2013[21] (Syria)	Randomized clinical trial	Fixed labial appliance (n = 17) Fixed lingual appliance (n = 17)	21.3 ± 3.1	Baseline (T0) Immediately (T1) 1 mo (T2) 3 mo (T3)	Chewing difficulties (questionnaire) Fixed labial appliance T0 vs T1 ($P = .02$) T0 vs T2 (NS) T0 vs T3 (NS) Fixed lingual appliance T0 vs T1 ($P < .001$) T0 vs T2 ($P = .009$) T0 vs T3 (NS)	N/A	N/A	Immediately after appliance placement, patients from fixed lingual appliances had more moderate to severe mastication impairment, while only 17.7% of patients using fixed labial appliances reported only moderate difficulties. After 1 mo, these differences were not significant.

Table 1. Continued

Author, Year (Country)	Study Design	Experimental Groups (N)	Mean Age ± Standard Deviation (Years)	Follow-Up Time (Before and After Installation)	Mastication Outcomes	Nutrition Outcomes	Pain After Activation	Main Conclusions
Lou et al., 2021[24] (Canada)	Non-randomized clinical trial (before-after study)	Clear Aligner (n = 17)	35.3 ± 17.6	Baseline 1, 2, 3, and 4 wk	EGM Masseter	N/A	N/A	Clear aligner therapy produces a transient increase in masseter muscle activity within the first 2 wk of treatment and decreases towards baseline thereafter.
Magalhães et al., 2014[4] (Brazil)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 27)	21.1 ± 10.4	Before (T0) Immediately (T1) 48 h (T2) 1 mo (T3) 3 mo (T4)	Masticatory performance (X_{50}) 5.6 ± 1.0 (T0) 5.9 ± 1.1 (T1) 7.5 ± 2.8 (T2) 5.9 ± 1.4 (T3) 5.9 ± 1.5 (T4) Swallowing threshold (X_{50}) 4.6 ± 1.3 (T0) 4.5 ± 1.2 (T1) 5.6 ± 3.2 (T2) 4.5 ± 1.5 (T3) 4.2 ± 1.1 (T4) Swallowing threshold (number of cycles) 34.2 ± 14.7 (T0) 30.6 ± 11.4 (T1) 34.4 ± 13.4 (T2) 32.2 ± 12.4 (T3) 32.4 ± 13.5 (T4)	N/A	VAS (mm) 10.9 ± 17.2 (T0) 22.5 ± 20.3 (T1) 52.7 ± 34.4 (T2) 17.8 ± 22.9 (T3) 7.4 ± 15.5 (T4)	Masticatory performance is reduced, and the swallowing threshold for harder foods is increased at the peak of orthodontic pain (48 h after archwire placement). At long-term follow-up examination, masticatory and swallowing performances return to those observed before the appliance placement.
Mansor et al., 2012[18] (Malaysia)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 60)	17.8 ± 3.1	Before (T0) 24 h (T1)	OHIP-16 (Eating avoidances) 1.8 ± 1.0 (T0) 4.2 ± 1.0 (T1)	N/A	OHIP-16 2.0 ± 0.8 (T0) 3.5 ± 1.2 (T1)	OHRQoL deteriorates 24 h after insertion of fixed orthodontic appliances, with significant impact over the masticatory capacity.
Prema et al., 2019[19] (India)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 30)	N/A	Baseline (T0) 1 wk (T1) 1 to 6 mo (T2–T7)	Bite Force (N) 469.4 ± 69.2 (T0) 191.7 ± 62.9 (T1) 230.6 ± 60.9 (T2) 257.3 ± 42.4 (T3) 306.6 ± 52.2 (T4) 320.6 ± 48.1 (T5) 343.9 ± 42.8 (T6) 389.2 ± 38.6 (T7)	N/A	N/A	Bite force is reduced to 50% of the pretreatment level during the first week of fixed labial appliance. After aligning and leveling stage, the bite force reaches the baseline level in hyperdivergent treatment group, while it reaches close to pretreatment level in hypodivergent and normodivergent treatment groups.
Riordan et al., 1997[20] (USA)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 10)	12–16 y	Baseline (T0) 72 h (T1)	N/A	3 days-dairy Cooper 1.23 ± 0.61 (T0) 0.85 ± 0.69 (T1) (*P* = .002) Manganese 2.85 ± 1.63 (T0) 2.08 ± 2.06 (T1) (*P* = .016) Calories from fat 49.32% to 55.54% Calories from carbohydrates 36.71% to 32.14%.	N/A	It may be beneficial to provide nutritional guidance to orthodontic patients to increase the copper and manganese content of the diet. Further research with a larger sample size would uncover the magnitude of the effects of orthodontic treatment on nutrient intake.

Table 1. Continued

Author, Year (Country)	Study Design	Experimental Groups (N)	Mean Age ± Standard Deviation (Years)	Follow-Up Time (Before and After Installation)	Mastication Outcomes	Nutrition Outcomes	Pain After Activation	Main Conclusions
Trein et al., 2013[3] (Brazil)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 10)	17.3 ± 5.2	Baseline (T0) 24 h (T1) 1 mo (T2)	Masticatory performance (X_{50}) 7.01 ± 2.9 (T0) 10.2 ± 1.1 (T1) 6.8 ± 1.3 (T2) Swallowing threshold (X_{50}) 5.5 ± 2.4 (T0) 6.2 ± 2.1 (T1) 5.9 ± 2.4 (T2) Swallowing threshold (number of cycles) 26.7 ± 9.1 (T0) 31.4 ± 13 (T1) 23.3 ± 10.5 (T2)	N/A	VAS (mm) 0.60 ± 0.70 (T0) 66.2 ± 34.5 (T1) 3.20 ± 3. (T2)	Masticatory performance of orthodontic patients significantly reduces 1 d after installation and activation of fixed labial appliance appliances. This period represents the peak time of orthodontic pain, which tends to decrease with time with consequently recovery of the mastication.
White et al., 2017[23] (USA)	Randomized clinical trial	Clear Aligner (n = 23) Fixed labial appliance (n = 18)	N/A	Baseline (T0) Day 1(T1) Day 2 (T2) Day 3(T3) Day 4 (T4) Day 5 (T5) Day 6 (T6) Day 7 (T7)	Difficult in chewing (VAS – mm) T0 - NS T1 - NS T2 – NS T3 – clear < labial ($P = .04$) T4 - clear < labial ($P = .03$) T5 – clear < labial ($P = .04$) T6 – clear < labial ($P = .01$) T7 - clear < labial ($P = .008$)	N/A	N/A	Immediately after appliance placement, fixed labial appliances produced more discomfort while chewing than did clear aligners. By day 7, patients in the aligner group experienced minimal discomfort, consistently less than baseline discomfort.
Wu et al., 2011[22] (Hong Kong)	Non-randomized clinical trial (before-after study)	Fixed labial appliance (n = 30) Fixed lingual appliance (n = 30)	Fixed labial appliance (20.3 ± 4.2) Fixed lingual appliance (21.6 ± 2.2)	1 to 12 wk 1 mo 3 mo	VAS (mm) Difficult in chewing – labial vs lingual – NS Difficult in biting – labial vs lingual – NS Difficult in swallowing – labial < lingual ($P < .05$)	VAS (mm) Dietary changes – labial < lingual – ($P < .001$) Avoidance of eating out - labial < lingual – ($P < .001$)	N/A	Regarding impact on mastication, there was no significant difference reported in biting or chewing between patients treated with labial and lingual orthodontic appliances. Oral impact disturbances were most common in the early phase of treatment. By the end of 3 mo, oral impacts were comparable for those treated with labial and customized lingual appliances.

Mastication was objectively assessed by masticatory performance (X_{50}),[3,4,15,16] swallowing threshold (particle size and number of cycles),[3,4,17] maximum bite force,[14,19] masseter muscle electromyography,[17,24] subjective mastication (visual analogue scale of 10 cm),[22,23] and questionnaires.[6,18,21,25] Only one study[20] reported data regarding nutritional assessment before and after the activation of a fixed labial appliance (3-day diet diary).

Risk of Bias

The risk of bias of individual studies is summarized in Figure 2 and Supplemental Tables 4 and 5. The RCTs[21,23] presented serious risk only for outcome measurements since mastication was subjectively assessed through self-reported questionnaires. No serious problems were detected in the remaining domains (Figure 2A). For the non-randomized studies (before and after design), the risk of bias was considered low in four studies,[4,14,16,19] moderate in three,[3,15,24] and serious in the remaining six studies.[6,17,18,29,22,25] In the first domain, bias was considered serious[6,18,22,25] or moderate[3,15,20] due to confounding factors or small sample size. A poor description of patient eligibility criteria was also considered.[3,4,6,14–18,20,22,24,25] Intervention bias was considered moderate in three studies,[15,17,20] due to the poor description of eligibility criteria and patient selection. One study[6] used a retrospective design, increasing its risk of bias. Deviations of intended interventions were

Table 2. Results of Quality Assessment of Studies Included in Meta-Analyses (The Grading of Recommendations Assessment, Development and Evaluation – GRADE)

Certainty Assessment								
Outcome	N° of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Others	Certainty
Masticatory Performance	3	Before-after studies	serious[a]	serious[b]	not serious	serious[c]	none	⊕○○○ VERY LOW
Swallowing Threshold (particle size)	2	Before-after studies	not serious	not serious	not serious	very serious[c]	none	⊕⊕○○ LOW
Swallowing Threshold (n° of cycles)	2	Before-after studies	not serious	not serious	not serious	very serious[c]	none	⊕⊕○○ LOW
Bite Force	2	Before-after studies	not serious	very serious[d]	not serious	very serious[c]	none	⊕○○○ VERY LOW

[a] Risk of bias due to confounding, since inclusion criteria for patients of two of the included studies was not properly described.
[b] Significant heterogeneity ($I^2 = 78\%$) between studies at 24 h × 30 d comparisons.
[c] Sample size of < 400 participants among included studies.
[d] High heterogeneity ($I^2 = 94\%$) between studies.

considered low due to the short period of evaluation (24 hours to a month). No patients required changes in interventions. Only one study[25] excluded patients for not answering the questionnaire correctly. As for outcome measurement bias, four articles[6,17,22,24] presented moderate risk due to the lack of blinding or patient self-assessment, leading to erroneous results if instructions and training were not correctly delivered. Since the remaining 11 studies[3,4,14–16,18–21,23,25] evaluated only one intervention, blinding outcome assessors would not have been possible; therefore, the risk of bias was judged as low. No issues were detected in the reported results; thus, all studies were considered at low risk.

Level of Evidence

The GRADE evaluation of the included studies resulted in low and very low results (Table 2). Inconsistency was judged to be serious to very serious, and the risk of bias was deemed as not serious since the paired design reduced the influence of confounding factors. Significant heterogeneity between studies ($I^2 > 50\%$) rendered serious to very serious limitations to judgment for mastication. As for indirectness, none of the outcomes presented issues regarding applicability. Thus, they were judged as presenting no serious limitations. Imprecision was considered serious for all outcomes due to the small number of patients (<400), limiting effect size measurements.

Results of Individual Studies

Studies comparing the masticatory performance of fixed labial appliances presented homogeneous methods (Supplemental Table 5). Thus, meta-analyses were performed comparing the chewed particle size (X_{50}) (Figure 3). A significant particle size reduction was observed after 24 hours of activation (SMD: 1.069; 95% coefficient interval [CI]: 0.619 to 1.518, $P < .0001$) (Figure 3A). Comparing baseline to 30 days, differences were no longer observed (Figure 3B), and mastication was recovered entirely after 30 days of the activation (Figure 3C). The swallowing threshold was also analyzed by two studies[3,4] (Supplemental Table 3). No particle size changes were observed, and the number of masticatory cycles remained constant when comparing baseline to 48 hours or 30 days of fixed appliance activation ($P > .05$) (Figure 4). In contrast, maximum bite force was significantly reduced 1 week after fixed labial appliance activation (SMD: −2.542, 95% CI: −4.867 to −0.217, $P < .032$) (Figure 5). Only one study[20] reported nutritional outcomes before and after fixed labial appliance activation. Significant intake reduction of copper ($P = .0018$) and manganese ($P = .016$) were observed 3 days after activation. Increased total calories and saturated fat consumption (49.32% to 55.54%) was also observed, while the percentage of calories from carbohydrates (36.71% to 32.14%) decreased.

Only three studies[21,22,25] reported masticatory outcomes of patients using fixed lingual appliances, and two of them compared lingual to labial appliances.[21,22] However, none of them performed objective assessments of mastication, jeopardizing further analysis due to high methodological heterogeneity. A moderate to severe impairment on mastication was reported immediately after lingual bracket placement.[21,22] Patients treated with lingual appliances reported more discomfort, dietary changes, swallowing difficulties, speech disturbances, and social problems than those with labial appliances.[22] No significant differences were found in oral self-care and patient satisfaction;[22] however, patients from the lingual group were not yet completely satisfied with their masticatory ability.[21,25]

Three studies[6,23,24] evaluated patients using clear aligners and two of them[6,23] compared clear aligner wearers to fixed labial appliance patients. Similarly,

2A. RoB 2.0

Study	D1	D2	D3	D4	D5			Overall
Khattab et al, 2013[21]	Low	Low	Low	High	Low	-	-	**High**
White et al, 2017[23]	Low	Low	Low	High	Low	-	-	**High**

D1: Bias arising from the randomization process
D2: Bias due to deviations from intended intervention
D3: Bias due to missing outcome data
D4: Bias in measurement of the outcome
D5: Bias in selection of the reported result

2B. ROBINS-I

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Alajmi et al, 2020[6]	Serious	Serious	Serious	Low	Low	Moderate	Low	**Serious**
Alomari et al, 2012[14]	Low	Low	Low	Low	Low	Low	Low	**Low**
Gameiro et al, 2015[16]	Low	Low	Low	Low	Low	Low	Low	**Low**
Goldreich et al, 1994[17]	Low	Serious	Moderate	Low	Low	Moderate	Low	**Serious**
Hohoff et al, 2003[25]	Serious	Low	Low	Low	Moderate	Low	Low	**Serious**
Lou et al, 2021[24]	Low	Low	Low	Low	Low	Moderate	Low	**Moderate**
Magalhães et al, 2014[4]	Low	Low	Low	Low	Low	Low	Low	**Low**
Mansor et al, 2012[18]	Serious	Low	Low	Low	Low	Low	Low	**Serious**
Prema et al, 2019[19]	Low	Low	Low	Low	Low	Low	Low	**Low**
Riordan et al 1997[20]	Moderate	Serious	Moderate	Low	Low	Low	Low	**Serious**
Silva Andrade et al, 2018[15]	Moderate	Low	Moderate	Low	Low	Low	Low	**Moderate**
Trein et al, 2013[3]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Wu et al, 2011[22]	Serious	Low	Low	Low	Low	Moderate	Low	**Serious**

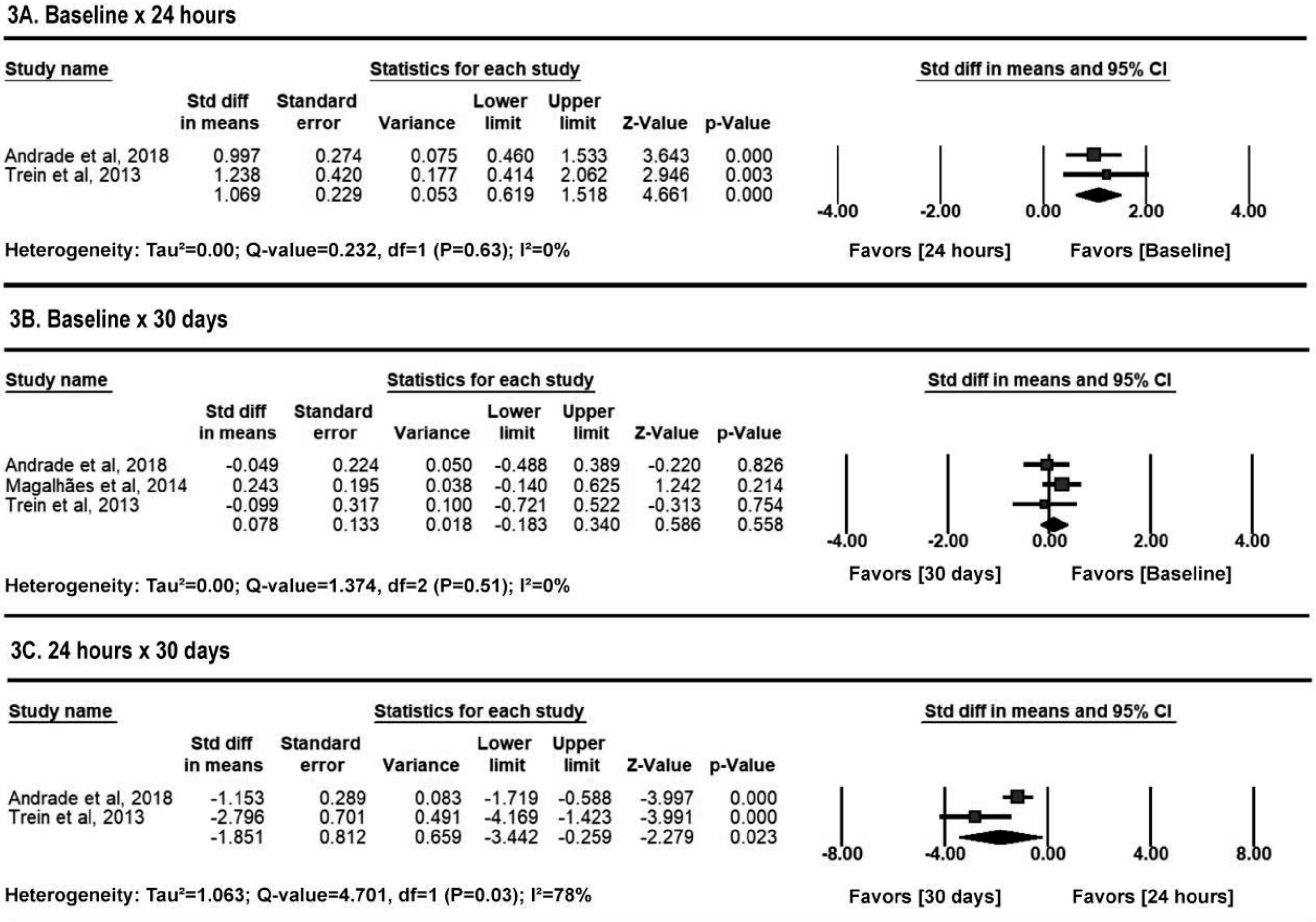
D1: Bias due to confounding
D2: Bias due to selection of participants
D3: Bias in classification of interventions
D3: Bias due to deviations of intended interventions
D5: Bias due to missing data
D6: Bias in measurement of outcomes
D7: Bias in selection of the reported result

Figure 2. Risk of bias summary of reviewer judgments about each risk of bias item according to the different study designs. (A) Risk of bias assessment for randomized clinical trials (ROB 2.0 tool); (B) Risk of bias assessment for Nonrandomized studies (ROBINS-I tool).

these studies evaluated only subjective mastication[6,23] and muscle electromyography (EMG),[24] impairing further data analysis. Masseter muscle EMG increased just after the installation or activation of clear aligners.[24] However, these changes were transitory and, after 2 weeks, muscle activity returned to baseline levels.[24] Compared to clear aligner wearer, patients using fixed labial appliances reported greater masticatory discomfort, especially after installation or during the first 2 months of treatment.[6] Patients using clear aligners reported better chewing ability ($P < .001$), no food restrictions ($P = .02$), and less mucosal ulcerations ($P = .01$).[6] No significant differences in swallowing threshold were found between clear aligner and fixed appliance groups.[6]

DISCUSSION

In this review, masticatory performance (X_{50}) was significantly reduced after 24 hours of fixed labial appliance activation. Similarly, a significant reduction of bite force was also observed 1 week after fixed labial appliance activation. However, after 30 days, mastica-



3A. Baseline x 24 hours

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Andrade et al, 2018	0.997	0.274	0.075	0.460	1.533	3.643	0.000
Trein et al, 2013	1.238	0.420	0.177	0.414	2.062	2.946	0.003
	1.069	0.229	0.053	0.619	1.518	4.661	0.000

Heterogeneity: Tau²=0.00; Q-value=0.232, df=1 (P=0.63); I²=0%

3B. Baseline x 30 days

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Andrade et al, 2018	-0.049	0.224	0.050	-0.488	0.389	-0.220	0.826
Magalhães et al, 2014	0.243	0.195	0.038	-0.140	0.625	1.242	0.214
Trein et al, 2013	-0.099	0.317	0.100	-0.721	0.522	-0.313	0.754
	0.078	0.133	0.018	-0.183	0.340	0.586	0.558

Heterogeneity: Tau²=0.00; Q-value=1.374, df=2 (P=0.51); I²=0%

3C. 24 hours x 30 days

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Andrade et al, 2018	-1.153	0.289	0.083	-1.719	-0.588	-3.997	0.000
Trein et al, 2013	-2.796	0.701	0.491	-4.169	-1.423	-3.991	0.000
	-1.851	0.812	0.659	-3.442	-0.259	-2.279	0.023

Heterogeneity: Tau²=1.063; Q-value=4.701, df=1 (P=0.03); I²=78%

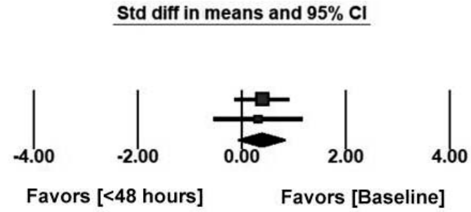
Figure 3. Forest plots of masticatory performance (X_{50}) after the activation of fixed labial appliances; (A) Comparisons between baseline and 24 hours of activation; (B) Comparisons between baseline and 30 days of activation; (C) Comparisons between 24 hours and 30 days of activation).

tory performance and bite force were fully recovered. On the other hand, the swallowing threshold was not compromised by appliance activation. Nutritional evaluations were limited but indicated a reduction in copper and manganese levels. Similar results were previously reported, especially regarding masticatory performance.[3,4,16] Masticatory impairment might be related to an acute inflammation process and/or pain symptoms, which generally occur 24 to 48 hours after activation. However, subjects with poor mastication did not use more strokes to chew food (eg, did not increase the swallowing threshold), but usually swallowed larger particles.[4,26] Thus, progressive tooth movement and temporary pain may not have been strong enough to cause swallowing interferences. Reductions in bite force were also expected since bite force is one of the most critical factors of masticatory performance variability ($R^2 = .55$, $P < .001$)[27] and because bite force reduction can be related to transient occlusal changes or periodontal mechanoreceptor sensibility.[14,19] Occlusal changes explained 10%–20% of maximum bite force variation in adults.[28] Just after initial bonding of appliances, greater deflection of the archwires to obtain bracket engagement may lead to greater pain, consequently affecting bite force.[29] In addition, the pain symptoms are higher in the first 48 hours after installation, reducing bite force and masticatory performance.

Dietary changes are commonly reported by patients using orthodontic appliances. However, in this review, only one study[20] reporting nutritional outcomes was found, preventing further analysis, but showing that copper and manganese blood levels apparently decreased.[20] Copper is essential for hemoglobin formation and iron transport for red blood cell production.[30] At the same time, manganese plays a crucial role in bone remodeling and glucose metabolism.[30] Deficiencies of these nutrients are linked to anemia, neutropenia, bone disease, reproductive problems, and impaired glucose tolerance.[31] Rich copper and manganese sources include shellfish, organ meats, nuts, whole grains, and raw vegetables. These are types of food which are commonly avoided by orthodontics patients. Increased total calories and

4A. Particle size (Baseline x <48 hours)

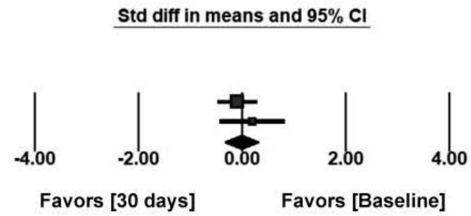
Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Magalhães et al, 2014	0.395	0.268	0.072	-0.130	0.921	1.475	0.140
Trein et al, 2013	0.325	0.435	0.189	-0.528	1.178	0.746	0.456
	0.376	0.228	0.052	-0.071	0.823	1.647	0.100



Heterogeneity: Tau²=0.00; Q-value=0.019, df=1 (P=0.89); I²=0%

4B. Particle size (Baseline x 30 days)

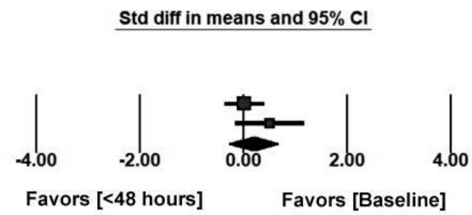
Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Magalhães et al, 2014	-0.091	0.193	0.037	-0.469	0.287	-0.472	0.637
Trein et al, 2013	0.199	0.319	0.102	-0.427	0.825	0.622	0.534
	-0.014	0.165	0.027	-0.337	0.310	-0.083	0.934



Heterogeneity: Tau²=0.00; Q-value=0.604, df=1 (P=0.44); I²=0%

4C. Masticatory Cycles (Baseline x <48 hours)

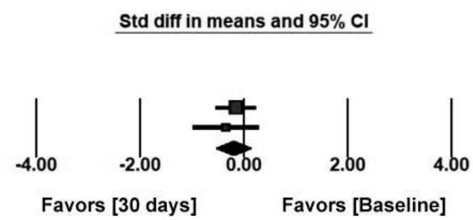
Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Magalhães et al, 2014	0.018	0.192	0.037	-0.359	0.395	0.092	0.927
Trein et al, 2013	0.515	0.337	0.113	-0.145	1.174	1.529	0.126
	0.190	0.236	0.056	-0.274	0.653	0.802	0.423



Heterogeneity: Tau²=0.05; Q-value=1.643, df=1 (P=0.20); I²=39%

4D. Masticatory Cycles (Baseline x 30 days)

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Magalhães et al, 2014	-0.151	0.194	0.037	-0.530	0.228	-0.780	0.435
Trein et al, 2013	-0.341	0.325	0.106	-0.978	0.297	-1.047	0.295
	-0.201	0.166	0.028	-0.527	0.125	-1.206	0.228

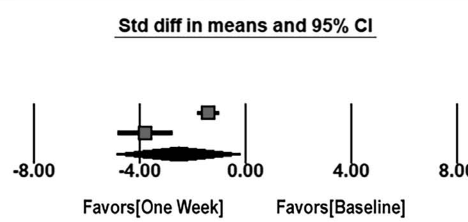


Heterogeneity: Tau²=0.05; Q-value=0.251, df=1 (P=0.62); I²=0%

Figure 4. Forest plots of swallowing threshold (particle size and the number of cycles) after the activation of fixed labial appliances. (A) Comparisons between baseline and < 48 hours; (B) Comparisons between baseline and 30 days of activation; (C) Comparisons between baseline and < 48 hours; (D) Comparisons between baseline and 30 days of activation.

Baseline x One week

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Alomari et al, 2012	-1.403	0.205	0.042	-1.806	-1.000	-6.829	0.000
Prema et al, 2019	-3.777	0.521	0.271	-4.798	-2.757	-7.254	0.000
	-2.542	1.186	1.407	-4.867	-0.217	-2.143	0.032



Heterogeneity: Tau²=2.66; Q-value=17.989, df=1 (P=0.00; I²=94%

Figure 5. Forest plots of bite force comparisons before and 1 week after the activation of fixed labial appliances.

saturated fat levels were also observed after activation of fixed labial appliances, with reduced carbohydrate intake.[20] Consistent with these findings, Shirazi et al.[32] showed a greater intake of fat and cholesterol and a lower intake of fiber, chromium, and beta-carotene in orthodontic patients. A high-fat diet is associated with obesity, increased risk of hypertension, cardiovascular disease, atherosclerosis, and noninsulin-dependent diabetes.[33] On the other hand, nutritional changes depend on several factors and are not automatically linked to masticatory improvement or impairment. Surprisingly, although orthodontic patients report eating difficulties, some of them also reported healthier eating habits.[34] Nevertheless, further research is encouraged to analyze long-term nutritional changes during orthodontic treatment.

Lingual fixed appliances are a good alternative for esthetic concerns during treatment,[35] but specific information regarding their masticatory and nutritional effects is scarce. According to Hohoff et al.,[25] patients reported more chewing difficulties just after installation. In addition, fixed lingual appliance wearers were more prone to mastication impairment than those using fixed labial appliances, especially after appliance placement.[21] On the other hand, Wu et al.[22] reported no differences in biting or chewing between patients treated with labial and lingual appliances. Nevertheless, due to these contrasting results, future studies are encouraged.

Regarding clear aligners, only three studies[6,23,24] reported masticatory outcomes, but none mentioned nutrition analysis. Masseter muscle activity increased within the first 2 weeks of clear aligner use.[24] Compared to fixed labial appliances, clear aligner wearers reported less chewing discomfort,[6,23] which might be related to temporary removal of the aligners during meals.[6]

Limitations including a lack of high-quality studies, small sample sizes, limited follow-up periods, subjective outcomes, and insufficient evidence to support further conclusions were observed, especially regarding lingual appliances and clear aligners. Future studies are needed to better elucidate the masticatory and nutritional alterations during different modes of orthodontic treatment. The influence of different malocclusions and multiple follow-up periods should also be evaluated in future studies.

Conclusions

- The activation and/or installation of fixed labial appliances temporarily reduces masticatory performance and bite force (24 to 48 hours). However, after 30 days, masticatory function is completely recovered.
- Due to insufficient data, the nutritional impact of orthodontic appliances was not conclusive.
- Future evidence from well-designed studies is necessary to better understand the impacts of clear aligners and lingual appliances.

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SUPPLEMENTAL DATA

Supplemental Tables available online.

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