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*Systematic Review*

# Complications Arising Due to Orthodontic Treatment—A Systematic Review and Meta-Analysis

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**Abstract:** A variety of metals and alloys are employed in the field of orthodontics, of which the construction of wires happens to be predominant. Through this systematic review, our primary goal was to review and assess studies focusing on complications that emerged during or directly after the completion of an orthodontic treatment plan. We then used a meta-analysis to determine how these complications affected the patients who were receiving orthodontic treatment. A total of 634 documents were discovered after a thorough search of online journals, and 416 of the papers were initially selected. In the end, 14 papers, including in vitro experiments, literature reviews, comparative analyses, observational studies, and retrospective studies, were chosen that met the requisite inclusion and exclusion criteria. There were difficulties related to orthodontic treatment in all of the studies listed in our systematic review, but their severity varied greatly. The effects of gingival mucosa and root resorption were two of the most often mentioned periodontal problems in this review. More long-term studies are required to confirm the involvement of an orthodontic component in these issues, but the majority of the complications were assessed to initially arise after the treatment plan had begun and to resolve with time.

**Keywords:** complications; mucosal damage; orthodontics; orthodontic appliances; periodontitis



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## 1. Introduction

Untreated malocclusion has been demonstrated to have detrimental psychological, social, and physical effects that can lower quality of life in terms of oral health [1]. The goals of orthodontic therapy include enhancing the function and appearance of the teeth; enhancing psychosocial well-being; and lowering the chance of long-term issues brought

on by malocclusion, such as tooth wear, gingival issues, and pathologies associated with impacted teeth [2]. The demand for orthodontic treatment still outstrips supply, despite accounting for about one-tenth of the NHS dental primary care expenditure in England, which was £3.4 billion in 2015–2016 [3]. According to the 2013 Child Dental Health Survey, 9% of 12-year-olds and 18% of 15-year-olds, respectively, were receiving orthodontic treatment, but an additional 37% and 20% of those 12- and 15-year-olds were found to need orthodontic treatment [4].

The standard of treatment must be evaluated using patient-reported outcome measures (PROMs) and patient-reported experience measures (PREMs) [5]. While PREMs offer information about the actual process of getting care, PROMs help to assess the effectiveness and safety of care from the perspective of the patient [6]. However, orthodontic study is increasingly including patient-reported measures, such as pain during treatment, expectations of treatment, and quality of life factors (impact of malocclusion, acceptability of treatment, anxiety, and occlusion) [7]. Currently, clinical care does not commonly use orthodontic-specific protocols in this respect. One of the most commonly assessed patient-reported outcomes in both study and audit is patient satisfaction.

One tool designed specifically for orthodontics to gauge parent satisfaction with young patients' orthodontic treatment takes into account both the procedure and the results [8]. Some other studies have also reported the effects of patient perception regarding the various facets of orthodontic treatment modalities [9,10]. Despite being a frequent indicator, contentment may not be able to distinguish between different facets of care, and may have a "ceiling" effect that can mask unpleasant experiences while receiving care [11].

The COVID-19 epidemic, which first surfaced two years ago, interrupted the world's medical and dental services [12,13]. The best recommendations for helping patients deal with orthodontic emergencies right away have been collected in this review. The following suggestion was made: when providing in-person treatment, strictly adhere to infection control guidelines after providing initial treatment guidance online at first [14]. In addition to acute orthodontic emergencies, there are other issues that could have varying effects on the course of therapy. It is crucial to draw attention to these issues in this unusual circumstance because they are linked to the stage of treatment, whether in the active or passive stages of orthodontic treatment. During the COVID-19 pandemic, many orthodontic patients were faced with delays in treatment. As a result of the pandemic, orthodontic practices were forced to close or limit their services to help prevent the spread of the virus [12]. This meant that patients with ongoing orthodontic needs had to put their treatment on hold, which could have caused complications or setbacks in their treatment progress [13]. Additionally, some patients who were in the middle of their orthodontic treatment when the pandemic hit may have experienced difficulty in scheduling follow-up appointments or adjustments due to closures or limited availability of their orthodontist. These delays and setbacks have been frustrating for patients, and have added to the already stressful situation of the pandemic [14].

Therefore, our main objective in conducting this systematic review was to examine and evaluate studies that looked at complications that occurred during or immediately following the conclusion of an orthodontic treatment plan, and to assess the impact of these complications on patients who were undergoing orthodontic treatment by the means of a meta-analysis.

## 2. Materials and Methods

### 2.1. Study Design

This systematic review was performed as per the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) strategy (Figure 1) and rules from the Cochrane group and the book *Orderly Reviews in Health Care: Meta-Examination* [15]. The current systematic review has been registered (CRD42022380829) with PROSPERO.

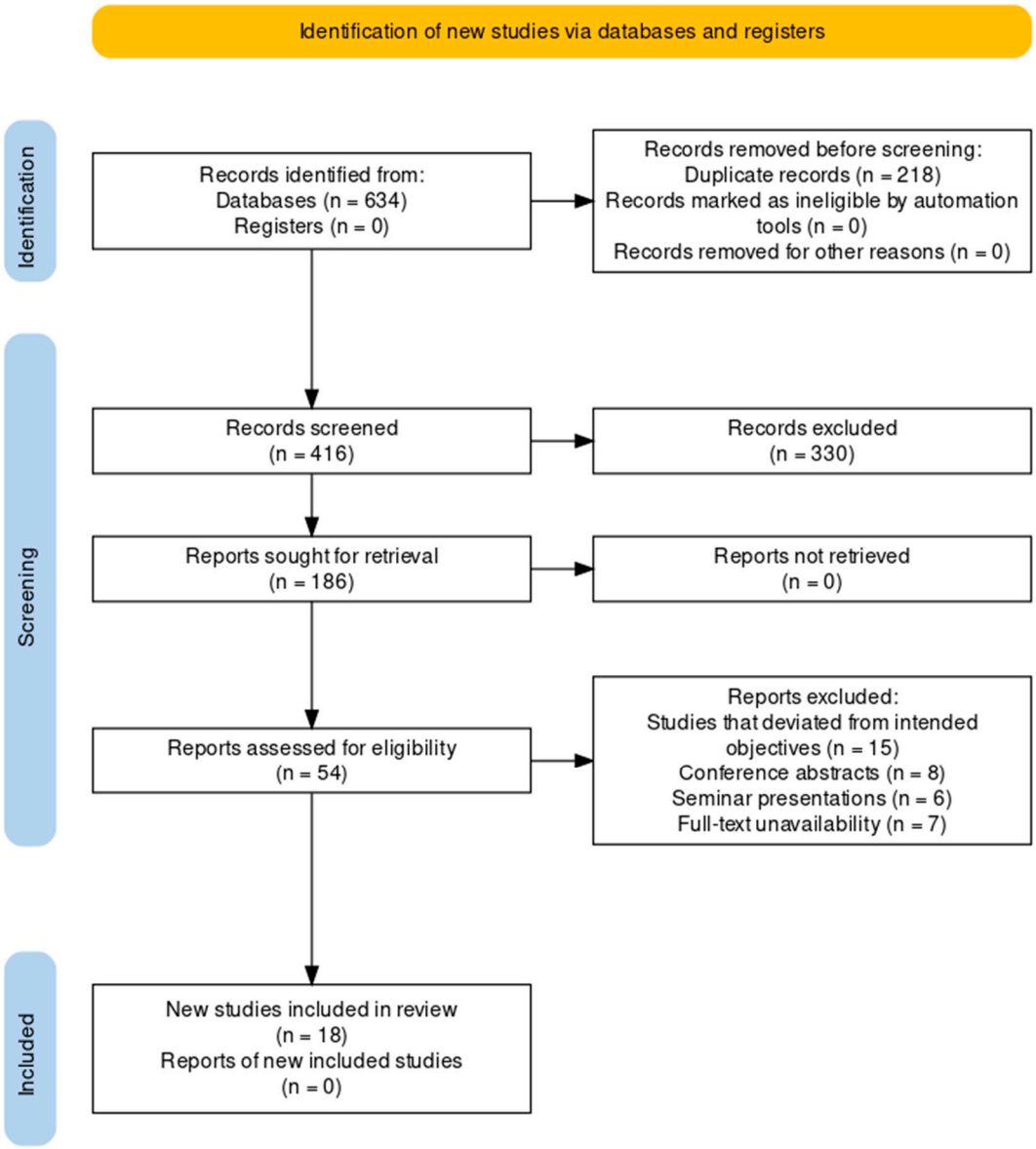


**Figure 1.** Article selection framework as per PRISMA protocol.

### *2.2. Clinical Question Explored*

In this systematic review, our major goal was to assess studies that observed incidences of complications during or directly after the completion of a complete orthodontic treatment plan. Additionally, we also selected some studies that made mention of a comparative evaluation between two orthodontic appliances/devices, with respect to which was more prone to causing complications in the patients.

### *2.3. Inclusion Criterion*

The inclusion criteria employed for this investigation were as follows:

- Studies that reported on complications arising due to orthodontic treatment in children and adults;
- Studies that reported on orthodontic treatments, including fixed appliances, removable appliances, clear aligners, or other types of orthodontic devices;
- Studies that reported on outcomes related to complications, including root resorption, periodontal disease, caries, pain, discomfort, or any other complications related to orthodontic treatment;

- Studies that reported comparisons between different types of orthodontic treatments, such as clear aligners vs. fixed appliances, or other comparisons;
- Studies that were conducted in humans.

### 2.4. Exclusion Criteria

The following types of articles were excluded from the scope of our systematic review:

- Studies that were not available as full texts or were not written in English;
- Studies that did not report on complications arising due to orthodontic treatment;
- Studies that reported on complications related to other dental treatments or surgeries, such as tooth extraction or implant placement;
- Studies that reported on orthodontic treatment in animals or in vitro studies;
- Studies that reported on orthodontic treatments that were not commonly used, such as self-ligating brackets or other unusual modalities;
- Case reports or case series;
- Studies that had atrociously low sample sizes (<10 participants);
- Studies that were duplicates or reported on the same population, intervention, or outcomes as other studies already included in the review.

### 2.5. Search Strategy

In the beginning, we identified the relevant databases for conducting the search. PubMed, Scopus, Cochrane Library, and Web of Science were selected for the purpose of conducting this investigation, after which we developed a search strategy using a combination of medical subject headings (MeSH), terms, and keywords related to our research question and eligibility criteria, which were "Complications," "Mucosal damage," "Orthodontics," "Orthodontic appliances," and "Periodontitis". Using this, we recorded the search terms, the number of articles retrieved, and the date of the search, following which the retrieved articles were screened for eligibility criteria. This process was performed in two stages: title and abstract screening, followed by full-text screening. The number of included and excluded articles was recorded at each stage. In the conclusive stage of this strategy, data from the included studies were extracted using a pre-defined data extraction form. The search strategy used Boolean operators across PubMed, Scopus, Cochrane Library, and Web of Science for the provided research question and eligibility criteria:

((Complications [MeSH Terms]) OR Mucosal Damage [MeSH Terms]) OR Orthodontics [MeSH Terms]) OR Orthodontic Appliances [MeSH Terms]) OR Periodontitis [MeSH Terms]) AND ((("complications" OR "mucosal damage" OR "orthodontics" OR "orthodontic appliances" OR "periodontitis"))) AND (English [Language] AND (("1 January 2017": "1 November 2022")).

This search strategy included medical subject headings (MeSH terms) including the terms "Complications," "Mucosal Damage," "Orthodontics," "Orthodontic Appliances," and "Periodontitis." The Boolean operator "OR" was used to combine the MeSH terms with their corresponding keywords. The Boolean operator "AND" was used to combine the search terms related to the research question and eligibility criteria. Additionally, the search strategy included language-based eligibility criteria, including only English language articles, and criteria regarding the time period for article selection, which was from 1 January 2017 to 1 November 2022.

### 2.6. Data Gathering Protocol

Two independent reviewers extracted the data from the included studies, using the data extraction form, to guarantee their accuracy and reliability. Any disagreements were clarified through conversation or communication with a different reviewer. Utilizing a standardized tool, the included studies' quality was evaluated, and the findings were documented using a particular data extraction form. After that, the data were subjected to a meta-analysis, which synthesizes the findings of various studies to produce an overall estimate of impact size. Finally, using the appropriate tables, graphs, and descriptive

statistics, the results of the systematic review and meta-analysis were presented in a straightforward, comprehensible, and succinct way.

### *2.7. Statistical Analysis*

The data were picked based on information regarding the sample size, factors examined, and various features of the research before being entered into the Revman 5 program for meta-analysis. Figures 2–4 depict forest plots that were obtained as part of our study's meta-analysis, and show the odds ratios for various study methodologies.

### *2.8. Risk of Bias Assessment*

The AMSTAR-2 technique [16] was used to evaluate the risk of bias in the studies we chose. AMSTAR 2 joins a number of other instruments that have been released for this purpose, for use in systematic reviews (Figure 2). The AMSTAR 2 risk of bias items identified the domains specified in the Cochrane risk of bias instrument for systematic reviews. In each case, this indicates an agreement achieved after input from more than 30 methodology experts.

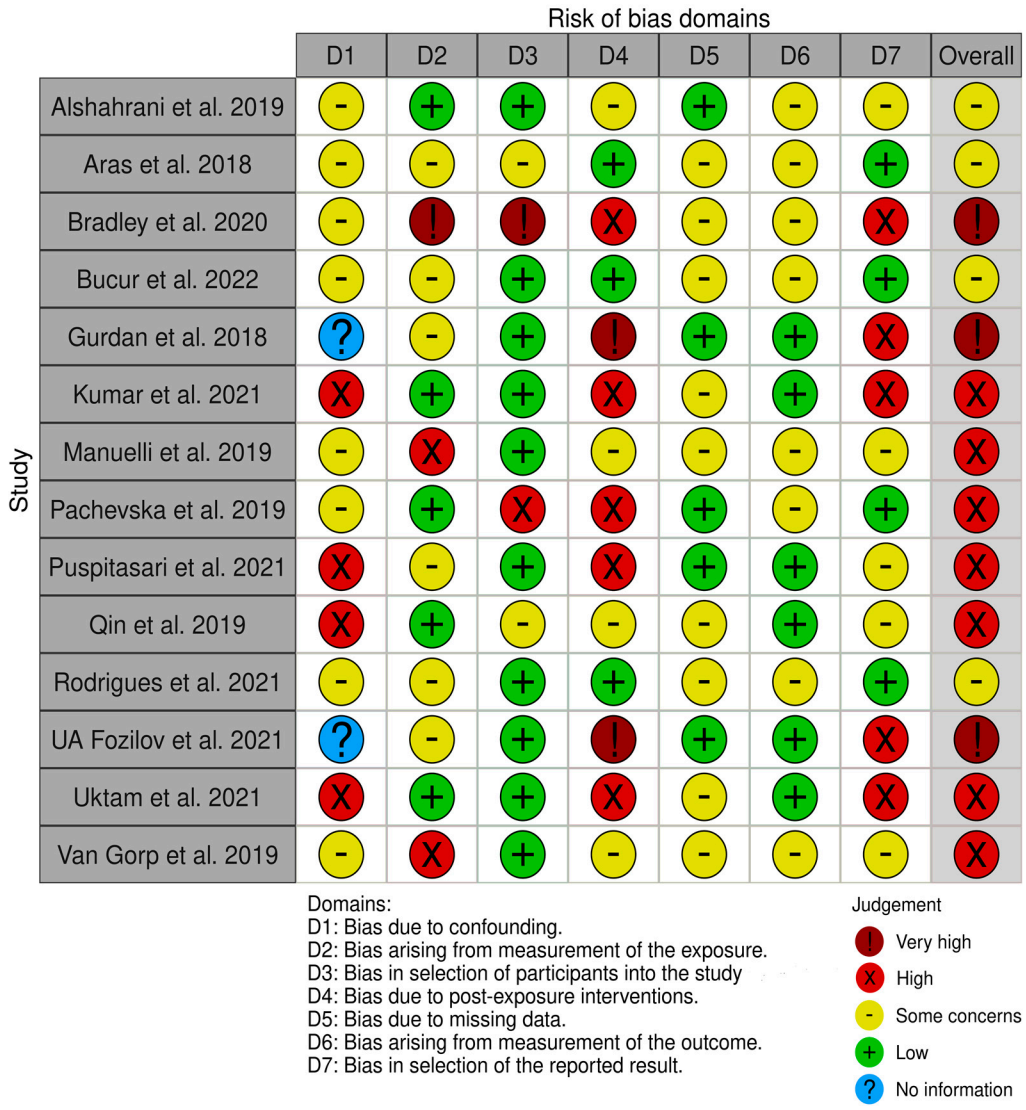


**Figure 2.** AMSTAR-2 16-point checklist of risk of bias assessment in studies selected for the systematic review [17–30].

| Study or Subgroup | Noticeable impact Events | Total | Negligible impact Events | Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Alshahrani et al 2019 | 17 | 60 | 43 | 60 | 7.1% | 0.16 [0.07, 0.35] |
| Aras et al 2018 | 19 | 32 | 13 | 32 | 6.3% | 2.14 [0.79, 5.79] |
| Bradley et al 2020 | 68 | 203 | 135 | 203 | 8.5% | 0.25 [0.17, 0.38] |
| Bucur et al 2022 | 51 | 116 | 65 | 116 | 8.2% | 0.62 [0.37, 1.03] |
| Gurdan et al 2018 | 23 | 59 | 36 | 59 | 7.3% | 0.41 [0.19, 0.86] |
| Kumar et al 2021 | 71 | 120 | 49 | 120 | 8.2% | 2.10 [1.25, 3.51] |
| Manuelli et al 2019 | 58 | 100 | 42 | 100 | 8.0% | 1.91 [1.09, 3.34] |
| Pachevska et al 2019 | 34 | 100 | 66 | 100 | 7.9% | 0.27 [0.15, 0.48] |
| Puspitasari et al 2021 | 5 | 23 | 18 | 23 | 4.8% | 0.08 [0.02, 0.31] |
| Qin et al 2019 | 43 | 98 | 55 | 98 | 8.0% | 0.61 [0.35, 1.07] |
| Rodrigues et al 2021 | 51 | 148 | 97 | 148 | 8.3% | 0.28 [0.17, 0.45] |
| UA Fozilov et al 2021 | 88 | 201 | 113 | 201 | 8.6% | 0.61 [0.41, 0.90] |
| Uktam et al 2021 | 82 | 201 | 119 | 201 | 8.6% | 0.47 [0.32, 0.71] |
| Van Gorp et al 2019 | 0 | 267 | 0 | 267 | | Not estimable |
| **Total (95% CI)** | | **1728** | | **1728** | **100.0%** | **0.51 [0.33, 0.79]** |
| Total events | 610 | | 851 | | | |

Heterogeneity: $Tau^2 = 0.56$; $Chi^2 = 97.76$, $df = 12$ ($P < 0.00001$); $I^2 = 88\%$

Test for overall effect: $Z = 2.99$ ($P = 0.003$)

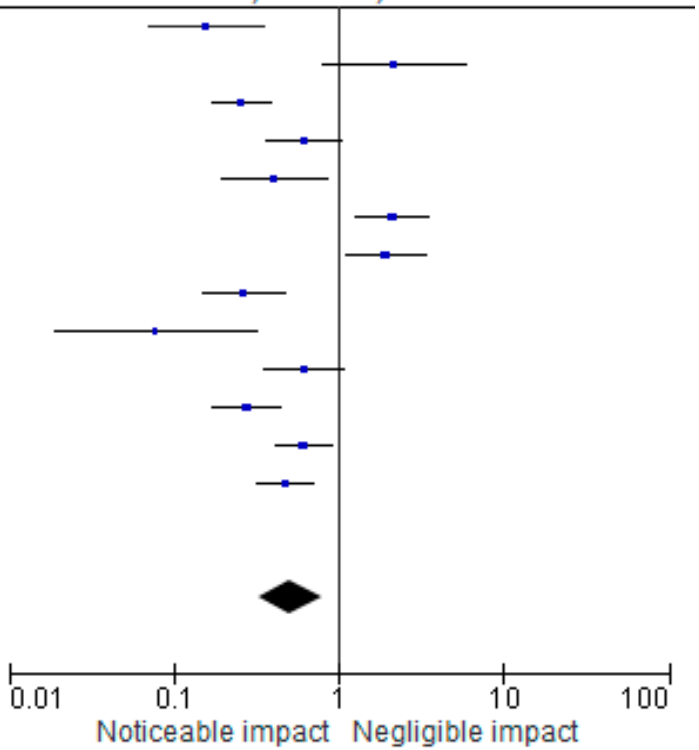


**Figure 3.** Odds ratio of clinical trials [17–30] selected in this systematic review and the impact of complications reported within them, displayed on a forest plot after meta-analysis.

| Study or Subgroup | Noticeable impact Events | Total | Negligible impact Events | Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Alshahrani et al 2019 | 17 | 60 | 43 | 60 | 6.9% | 0.40 [0.26, 0.61] |
| Aras et al 2018 | 19 | 32 | 13 | 32 | 6.3% | 1.46 [0.88, 2.43] |
| Bradley et al 2020 | 68 | 203 | 135 | 203 | 8.6% | 0.50 [0.41, 0.63] |
| Bucur et al 2022 | 51 | 116 | 65 | 116 | 8.3% | 0.78 [0.60, 1.02] |
| Gurdan et al 2018 | 23 | 59 | 36 | 59 | 7.4% | 0.64 [0.44, 0.93] |
| Kumar et al 2021 | 71 | 120 | 49 | 120 | 8.3% | 1.45 [1.12, 1.88] |
| Manuelli et al 2019 | 58 | 100 | 42 | 100 | 8.1% | 1.38 [1.04, 1.84] |
| Pachevska et al 2019 | 34 | 100 | 66 | 100 | 8.0% | 0.52 [0.38, 0.70] |
| Puspitasari et al 2021 | 5 | 23 | 18 | 23 | 4.2% | 0.28 [0.12, 0.62] |
| Qin et al 2019 | 43 | 98 | 55 | 98 | 8.1% | 0.78 [0.59, 1.04] |
| Rodrigues et al 2021 | 51 | 148 | 97 | 148 | 8.4% | 0.53 [0.41, 0.68] |
| UA Fozilov et al 2021 | 88 | 201 | 113 | 201 | 8.7% | 0.78 [0.64, 0.95] |
| Uktam et al 2021 | 82 | 201 | 119 | 201 | 8.7% | 0.69 [0.56, 0.84] |
| Van Gorp et al 2019 | 0 | 267 | 0 | 267 | | Not estimable |
| **Total (95% CI)** | | **1728** | | **1728** | **100.0%** | **0.72 [0.58, 0.90]** |
| Total events | 610 | | 851 | | | |

Heterogeneity: Tau² = 0.13; Chi² = 90.82, df = 12 (P < 0.00001); I² = 87%

Test for overall effect: Z = 2.93 (P = 0.003)

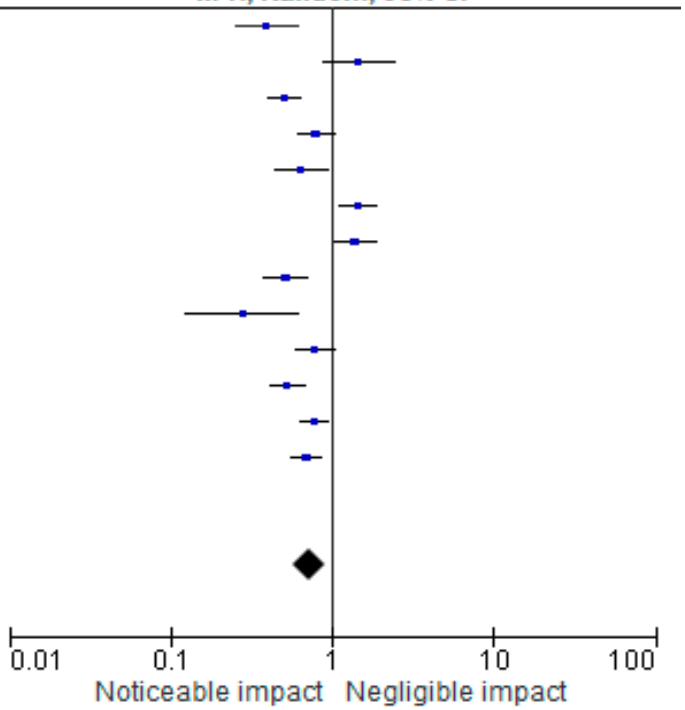


**Figure 4.** Risk ratio of clinical trials [17–30] selected in this systematic review and the impact of complications reported within them, displayed on a forest plot after meta-analysis.

## 3. Results

After the initial search strategy was completed, we encountered 634 papers pertinent to the study's objectives. In the second step, 416 articles remained after removal of duplicate studies/studies that were common with one another. Ultimately, in the final selection phase, 14 articles were generated after the application of all the inclusion and exclusion criterion.

Thirty studies were selected for the review, and their demographic characteristics were assessed in Table 1. The sample size ranged from 50 to 300, with no definitive parameters related to the age of the participants assessed across the studies. The male-to-female ratio was fairly balanced across the studies, ranging from 1:1.1 to 1:1.3. Out of these fourteen articles, one was a randomized control trial [24], four happened to be retrospective studies [17,20,21,26], one was a comparative study [18], three studies were of cross-sectional design [19,28,29], three studies were observational in protocol [22,23,25], and the remaining two utilized a questionnaire as their methodological approach [27,30].

The forest layouts from the 14 studies that were considered for the analysis are shown in Figures 3–5. After considering all pertinent factors related to the papers, the data were entered into the RevMan 5 software, and forest plots displaying the odds ratio, risk ratio, and risk difference related to the effect of the specific complication encountered in the respective study were produced and assessed. The meta-analysis employed a random effects model with a 95% confidence range. For each investigation, the total sample size was the total number of events, and a random effects model was applied.

Figure 3 displays the forest plot of the odds ratio obtained through the meta-analysis of clinical trials [17–30] that examined the impact of orthodontic complications on patients undergoing orthodontic treatment. The odds ratio was found to be 0.51 [0.33, 0.79], indicating that the intervention may be effective in reducing the risk of complications in the study population. The odds ratio of less than 1 suggests that patients who received the intervention (which differed from study-to-study as per the complication that was observed) had lower odds of experiencing orthodontic complications compared to those who did not receive the intervention. The confidence interval for the odds ratio ranged from 0.33 to 0.79, suggesting that the true effect size is likely to fall within this range. However, the wide range of the confidence interval indicates that the true effect size is uncertain. The heterogeneity statistics reported in the forest plot indicate that there is significant variation in the effect sizes reported across the studies included in the meta-analysis. The $Tau^2$ value of 0.56 suggests that there is substantial heterogeneity between the studies, while the $Chi^2$ value of 97.76, with 12 degrees of freedom and a $p$-value of <0.00001, indicates significant heterogeneity. The $I^2$ value of 88% indicates that a large proportion of the heterogeneity is due to true differences in effect sizes. The test for overall effect, with a Z-value of 2.99 and a $p$-value of 0.003, indicates that the overall effect of the intervention on reducing orthodontic complications is statistically significant. Overall, the forest plot suggests that the intervention may be effective in reducing the risk of orthodontic complications in patients undergoing orthodontic treatment. However, the wide confidence interval and significant heterogeneity highlight the need for further research to confirm the intervention's effects and explore the sources of heterogeneity.

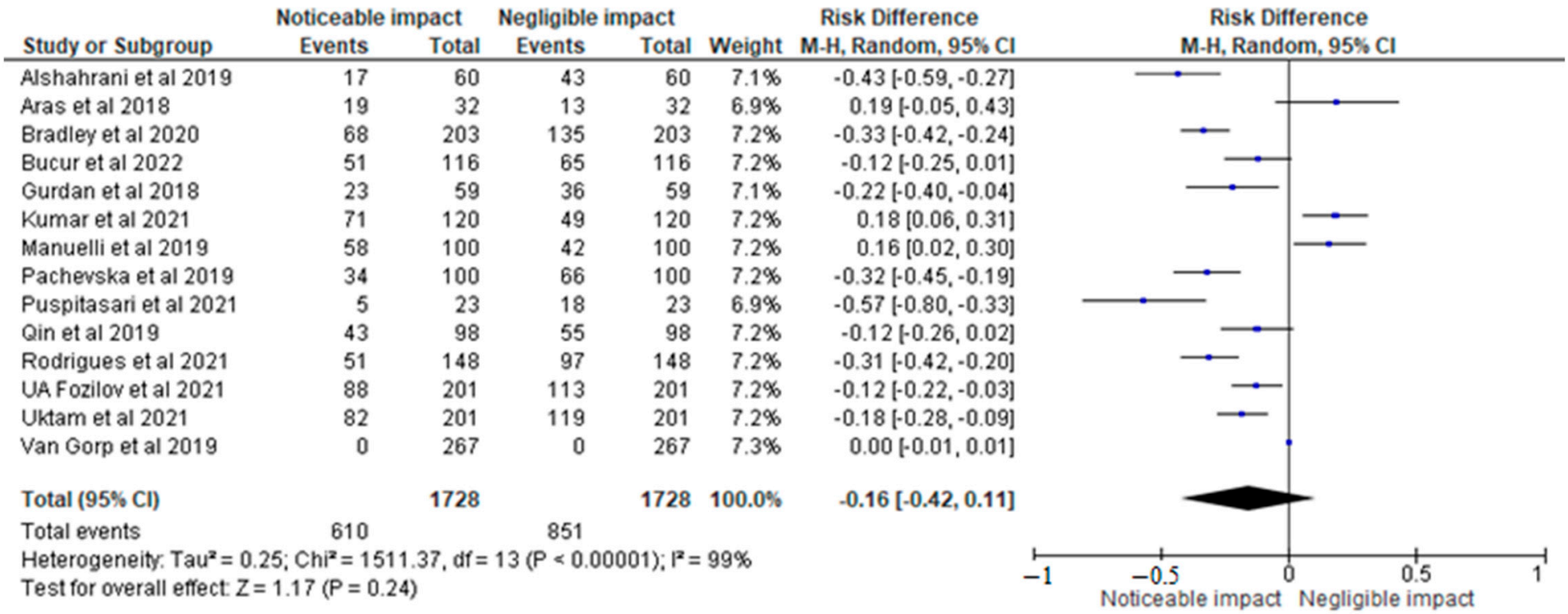


**Figure 5.** Risk difference of clinical trials [17–30] selected in this systematic review and the impact of complications reported within them, displayed on a forest plot after meta-analysis.

**Table 1.** Description and outcomes as observed in the studies selected for the systematic review.

| ID | Target Group Size | Mean Age and Male: Female Ratio | Protocol of the Study | Objectives of the Paper | Inference from the Article |
|---|---|---|---|---|---|
| Alshahrani et al., 2019 [17] | 60 patients | 21.7 years | Retrospective study | This study sought to assess how the key salivary parameters of patients receiving fixed orthodontic treatment were affected; 60 patients had saliva samples taken both before and two months after starting fixed orthodontic treatment. | The introduction of orthodontic appliances changed the properties of saliva in the oral cavity, as shown in this study by significant changes in salivary flow rate, pH, buffering capacity, and total protein concentration, as well as amylase, calcium, and glucose levels, before and after treatment started. |
| Aras et al., 2018 [18] | 32 subjects | - | Comparative study | The goal of this study was to use cone beam computed tomography to volumetrically assess external root resorption (ERR) caused by orthodontic treatment in maxillary incisors, utilizing self-ligating brackets or conventional brackets. | Although there were significant differences in root volume between the two groups, there was no difference in ERR between the groups. Similar volume reduction was seen in the central and lateral incisors of the maxilla. |
| Bradley et al., 2020 [19] | 203 subjects | 12+ years; 68:130 | Cross-sectional survey | This study's objective was to evaluate how orthodontic treatment affected patients' perceptions of their pre-treatment anxieties, their treatment experiences, and their treatment results. | Alignment (89%) and being ashamed to grin (63) were the most often expressed pre-treatment worries. The most often expressed hopes for orthodontic treatment were increased self-assurance when eating (87%) and smiling (72%) in public, improved dental health (85%), and a decrease in bullying/teasing (63%). The three most often reported problems were gingivitis (39%), sore mouth (68%), and fixed appliance breakage (61%). |
| Bucur et al., 2022 [20] | 116 adult patients | 18.3–27.6 years; 38.79:61.21 | Retrospective study | A total of 116 adult patients wearing various kinds of orthodontic retainers were included in this retrospective analysis. The Quigley-Hein plaque index and the Navy plaque index, both modified by Turesky and Rustogi, were utilized by the authors to calculate the accumulation of dental plaque on a quantitative basis. | It was revealed that plaque accumulation was much lower in the case of mobile retainer wearers than fixed retainer users. When fixed retainers were used, periodontal recessions occurred more frequently. |

**Table 1.** *Cont.*

| ID | Target Group Size | Mean Age and Male: Female Ratio | Protocol of the Study | Objectives of the Paper | Inference from the Article |
|---|---|---|---|---|---|
| Gurdan et al., 2018 [21] | 59 patients | Age not clearly defined; 25.4:74.6 | Retrospective study | This study aimed to calculate the success and complication rates of orthodontic mini-implants. | In this study, the success rate of the orthodontic mini-implants was 89.8%, and the typical loading time was 8.1 months. Infections of the soft tissues occurred in 6.3% to 33.3% of patients, whereas screw mobility occurred in 3.1% to 20.8% of cases, depending on the anatomic placement. |
| Kumar et al., 2021 [22] | 120 patients | 14.6 years; 47:73 | Observational study | The goal of this study was to evaluate the impact of fixed orthodontic therapy on gingival health. All patients' full medical histories were documented. | Before and after treatment, the mean visible plaque values were found to be 3.11 and 5.81, respectively. Before and after therapy, the mean visible inflammation values were found to be 2.89 and 15.43, respectively. Before and after treatment, the mean gingival recession score values were reported to be 0.19 and 0.383, respectively. |
| Manuelli et al., 2019 [23] | 100 patients | - | Observational study | The goal of this research was to evaluate the effects of fixed orthodontic devices on soft tissue, bone, and tooth lesions. For this purpose, 100 participants with fixed orthodontic appliances were included in the research. | Regarding RPE, palatal lesions were reversible in 35% of patients, while tongue impressions were caused by the device in 45% of patients. Five percent of the individuals had tooth lesions and periodontal issues (i.e., dental caries). White spot lesions (WSL) and dental decay affected 15% of the participants; periodontal disease affected 10% of those using the Forsus appliance; and cheek mucosal lesions affected 20% of the patients. |
| Pachevska et al., 2019 [24] | 100 children | 9–15 years; NA | Randomized control trial | On the basis studying clinical and biochemical indicators, the purpose of this research was to improve the efficacy of prevention of inflammatory complications in the provision of orthodontic care to children with dentomaxillary abnormalities using non-removable orthodontic devices. | The usage of non-removable orthodontic appliances caused oral cavity irritation. The oral fluid's levels of total protein, hydrogen sulfide, and nitrogen metabolites increased along with the decline in oral hygiene. |

**Table 1.** *Cont.*

| ID | Target Group Size | Mean Age and Male: Female Ratio | Protocol of the Study | Objectives of the Paper | Inference from the Article |
|---|---|---|---|---|---|
| Puspitasari et al., 2021 [25] | 23 samples | - | Observational study | In Makassar, Indonesia, dental students participated in this study to learn more about how fixed orthodontic therapy affects tooth discoloration. | In this study, 2 samples (8.7%) and 12 samples (52.2%), respectively, showed discoloration degrees of 1 and 2; 10 samples (66.7%) of the 15 samples with treatment durations longer than 12 months had deterioration degrees of 1; and 2 samples (13.3%) had discoloration degrees 2. In contrast, 6 (75%) of the 8 samples with a treatment period of less than 12 months had discoloration of degree 0, while 2 (25%) had discoloration of degree 1. |
| Qin et al., 2019 [26] | 98 patients | 15.18 years; 51:47 | Retrospective study | This study sought to determine whether traditional and passive self-ligating braces had any impact on the quantity and intensity of external apical root resorption (EARR) in patients undergoing withdrawal. | Between the two groups, there was no discernible variation in the amount of EARR. Age and gender did not correslate with EARR; however, EARR did positively correlate with the length of the treatment. In the end, in class I extraction patients, the kind of bracket had no bearing on the occurrence or intensity of the external apical root resorption. |
| Rodrigues et al., 2021 [27] | 148 subjects | 14–35 years; 20.7:79.3 | Questionnaire-based study | This questionnaire study was conducted to evaluate the typical gingival issues experienced by patients receiving fixed orthodontic treatment. | According to this study, the vast majority of patients in both groups were cautious about keeping up proper oral hygiene. Occasionally itchy, painful, and swollen gums, or bleeding gums, were also reported by a small number of patients in both therapy groups. |

**Table 1.** *Cont.*

| ID | Target Group Size | Mean Age and Male: Female Ratio | Protocol of the Study | Objectives of the Paper | Inference from the Article |
|---|---|---|---|---|---|
| UA Fozilov et al., 2021 [28] | 201 children | 7–18 years; 48.3:51.7 | Cross-sectional study | The major goal of this article was to make it easier to diagnose caries and associated problems during orthodontic treatment, and to prevent them from happening in the first place. | Children receiving orthodontic care exhibited elevated phosphorus levels, despite a tendency for calcium levels to drop, and normal pH levels. The evaluation of oral hygiene in the control groups based on the OHI-S and RNR indices was inadequate and went beyond the baseline indicators. |
| Uktam et al., 2021 [29] | 201 patients | 7–15 years; 48.3:51.7 | Cross-sectional study | This study's objective was to enhance the detection and mitigation of caries and related consequences during orthodontic treatment. | Prior to receiving orthodontic treatments, all patients who had exams exhibited poor oral hygiene, as well as a lack of drive to practice good oral hygiene and prevent dental illnesses. Manual oral care skills were good in 12% of patients at greater risk of dental caries, but unsatisfactory in 67%. According to the OHI-S index, the sanitary conditions in the preventative subgroups were satisfactory at the end of the study. |
| Van Gorp et al., 2019 [30] | 267 dentists | NA; 30.23:69.24 | Questionnaire-based study | The goal of this study was to assess dental professionals' understanding of this subject. In Flanders, general dentists, pediatric dentists, and orthodontists participated in a questionnaire survey (Belgium). | The most common adverse reaction in cases of ankylosis was noted to be difficulty in moving the tooth during orthodontic treatment. Tooth discoloration and apical root resorption were the two most commonly noted adverse reactions in cases with pulp and root canal obliteration. |

The risk ratio for the clinical trials [17–30] is shown in the forest plot of Figure 5. These trials investigated the impact of orthodontic complications on patients undergoing orthodontic treatment. The risk ratio found was 0.72 [0.58, 0.90], which suggests that the intervention may be effective in reducing the risk of complications in the study population. The risk ratio of less than 1 indicates that the patients who received the intervention (which differed from study-to-study as per the complication that was observed in it) had a lower risk of experiencing orthodontic complications compared to those who did not receive the intervention. The confidence interval for the risk ratio ranged from 0.58 to 0.90, indicating that the true effect size is likely to fall within this range. However, the wide confidence interval suggests some uncertainty regarding the true effect size of the intervention. The heterogeneity statistics reported in the forest plot indicate that there is significant variation in the effect sizes reported across the studies included in the meta-analysis. The $Tau^2$ value of 0.13 suggests that there is moderate heterogeneity between the studies, while the $Chi^2$ value of 90.82, with 12 degrees of freedom and a *p*-value of <0.00001, indicates significant heterogeneity. The $I^2$ value of 87% indicates that a large proportion of the heterogeneity is due to true differences in effect sizes. The test for overall effect, with a Z-value of 2.93 and a *p*-value of 0.003, indicates that the overall effect of the intervention on reducing orthodontic complications is statistically significant. Overall, the forest plot suggests that the intervention may be effective in reducing the risk of orthodontic complications in patients undergoing orthodontic treatment. However, the wide confidence interval and significant heterogeneity indicate that further research is needed to confirm the intervention's effects and explore the sources of heterogeneity.

The forest plot represented in Figure 5 shows the results of the meta-analysis that examined the impact of complications on the sample size, which consisted of patients undergoing orthodontic treatment in any form, as reported in the clinical studies [17–30]. The risk difference found was −0.16 [−0.42, 0.11], which suggests that the risk of complications might be lower in the group receiving the intervention (which differed from study-to-study as per the complication that was observed in it) compared to the control group. However, it is important to note that the confidence interval ranged from −0.42 to 0.11, which indicates that the true effect size may be anywhere within this range. The forest plot also reported heterogeneity statistics, which indicate how much variation existed between the studies included in the meta-analysis. The $Tau^2$ value of 0.25 suggests that there is substantial heterogeneity, meaning that the studies differ significantly from each other in terms of their effect sizes. The $Chi^2$ value of 1511.37, with 13 degrees of freedom and a *p*-value of <0.00001, indicates significant heterogeneity. The $I^2$ value of 99% suggests that almost all of the heterogeneity is due to true differences in effect sizes, rather than chance or sampling error. This high level of heterogeneity means that the studies may have different populations, interventions, or outcomes, which makes it difficult to draw firm conclusions from the meta-analysis. In summary, the forest plot suggests that the intervention may reduce the risk of complications, but the true effect size is uncertain due to the wide confidence interval and high level of heterogeneity. Future research should aim to address the sources of heterogeneity and provide more precise estimates of the intervention's effects.

## 4. Discussion

The significance of this study lies in its systematic approach to reviewing the literature on the metallurgical characteristics of metals and alloys used in orthodontic treatment, and the associated complications. By synthesizing the findings of 14 studies, this review provides a comprehensive overview of the difficulties related to orthodontic treatment and highlights the need for more long-term studies to confirm the involvement of an orthodontic component in these issues. The review's implications are threefold. Firstly, our findings identified gingival mucosa and root resorption as the most commonly reported periodontal problems associated with orthodontic treatment. Orthodontists can use this information to monitor patients for these complications and take preventive measures to minimize their occurrence. Additionally, this investigation highlights the need for more long-term

studies to confirm the involvement of orthodontic treatment in the identified complications. Future studies can build on the findings of this review to investigate the mechanisms underlying these complications and develop strategies to mitigate them. Moreover, this review can inform the education and training of orthodontic professionals by providing a comprehensive overview of the complications associated with orthodontic treatment. Educators can use this information to develop curricula that emphasize the importance of monitoring patients for these complications and taking preventive measures to minimize their occurrence.

Overall, this systematic review contributes to our understanding of the metallurgical characteristics of metals and alloys used in orthodontic treatment and the associated complications, providing a foundation for future research, clinical practice, and education in this field.

The duration of orthodontic treatment, the level of pain and discomfort, and the use of retention appliances, in contrast, were all linked to patient dissatisfaction. This was revealed by a systematic analysis of 18 studies [9] that looked at patient satisfaction with orthodontic treatment. The evaluation showed a wide range in terms of research design, setting, demographics, and measurement methods. According to a qualitative study [10], adult patients' satisfaction with their orthodontic care was correlated with communication, staff, the physical surroundings, appointments, and the impact of appliance therapy. Orthodontic treatment aims to move teeth to their desired positions, but this movement can result in some undesirable consequences, such as root resorption [31]. Root resorption occurs when the cells responsible for breaking down and rebuilding bone, known as osteoclasts and osteoblasts, respectively, become overactive and remove more tooth structure than necessary, leading to shorter roots [32–35]. Intrusion, retraction, and torque movements are common orthodontic tooth movements that have been investigated regarding their potential to cause root resorption [36–40]. While these movements alone may not increase the risk of root resorption, factors such as the amount of force applied, stress distribution region, and total apical displacement can make them more potent [41–43].

First, the amount of force applied is critical in determining the extent of root resorption. Studies have shown that higher forces lead to increased root resorption, with force levels above 2 N associated with a greater risk of resorption [35,44–47]. This is because high forces cause an imbalance between the forces applied to the tooth and the ability of the surrounding tissues to support them. As a result, the tooth moves faster than the surrounding bone can remodel, leading to hyalinization (death of cells) and resorption of the root [48–51].

Second, the stress distribution region can also affect the risk of root resorption [52–57]. When orthodontic forces are applied, they create stresses within the tooth and the surrounding bone. Areas of the tooth with the highest stress concentrations are at a greater risk of root resorption. For example, the apex of the tooth, where the forces are most concentrated, is more likely to experience resorption than the middle or the cervical regions [58–62].

Lastly, the total apical displacement of the tooth is also crucial in determining the risk of root resorption [37,63]. Greater displacement of the tooth can lead to increased hyalinization and resorption of the root. The longer the tooth is under tension, the more likely it is to undergo resorption [64]. All in all, while intrusion, retraction, and torque movements may not necessarily raise the risk of root resorption on their own, the amount of force applied, stress distribution region, and total apical displacement can make them more potent [65–68]. Therefore, it is essential to apply appropriate forces and carefully monitor the movement of the tooth to minimize the risk of root resorption. Orthodontists should consider these factors while planning and executing orthodontic treatment to achieve the desired results while minimizing the risk of undesirable outcomes.

The studies that are available demonstrate that aligners have a reduced risk of root resorption when compared to fixed appliances, despite the fact that there is little research on root resorption associated with aligner applications [31,38–40,69–74]. This could be as a result of the intermittent, comparatively light pressures that these appliances employ,

which result in less tooth movement and apical displacement. The cementum repair procedure is recommended in order to improve the likelihood of root healing. Additionally, in instances of mild crowding without the need for extractions, and for quicker treatment times, aligners are frequently advised [41,75–79]. Another element that impacts how well aligners function is patient compliance. Aligners transmit pressure more intermittently and for shorter periods of time when a patient is non-compliant, which lowers the risk of root resorption [35]. However, they can also produce jiggling forces [40,80–83]. This is not commonly reported [38], as determining its occurrence is difficult [38,81,84–87].

Surprisingly, none of the research studies we cited in our analysis looked at root resorption with regard to removable equipment. Strong forces led to a rise in root absorption. A significant correlation between root resorption and orthodontic force level was found in several systematic evaluations [25,35,38]. Several studies claim that there is only scant proof to back up this association [35,88,89]. Orthodontic treatment aims to correct malocclusions or misaligned teeth and jaws. While the majority of orthodontic treatments are successful, there are risks and complications associated with orthodontic treatment. Some patients may develop allergic reactions to the materials used in orthodontic appliances, such as metal wires or brackets [85,86]. This can cause discomfort, swelling, and even difficulty breathing in severe cases [86]. Orthodontic appliances can sometimes interfere with speech, causing a lisp or other speech impediments. This is more common with certain types of appliances, and not all of them [87]. It is common for patients to experience some discomfort during orthodontic treatment, particularly in the days after braces are tightened [88]. However, if the pain is severe or persistent, it could be a sign of a more serious problem, such as a loose bracket or wire [88]. Orthodontic appliances can also sometimes cause staining or discoloration of the teeth, particularly if the patient consumes certain foods or beverages that are known to stain teeth (such as coffee, tea, or red wine) [89]. This can be difficult to treat and may require professional teeth whitening after the braces are removed. In some cases, orthodontic treatment may actually cause bite problems, rather than correcting them [89]. For example, if the teeth are moved too quickly or too far, it can result in an open bite or crossbite. As we discussed earlier, root resorption is the primary complication arising due to these treatment modalities [90]. This is the shortening or loss of the tooth roots, which can occur when orthodontic forces are applied to the teeth [90]. Another is decalcification, which is caused by the breakdown of the tooth enamel due to poor oral hygiene, particularly around orthodontic appliances [91]. Gingivitis and periodontitis are conditions that affect the gums and can be caused by poor oral hygiene during orthodontic treatment [92]. When the teeth are not cleaned properly, the accumulation of plaque and tartar can lead to inflammation and infection of the gums. Conditions that affect the temporomandibular joint (TMJ) can also cause pain and discomfort in the jaw, face, and neck due to appliance usage [92]. This can occur when orthodontic forces are applied incorrectly or when there is a pre-existing problem with the TMJ [93]. Orthodontic appliances can also inadvertently result in orthodontic complications if they are not used correctly or if they are not properly maintained [94]. If brackets or wires break, they can cause discomfort, delay treatment, or even cause injury to the mouth or throat. If appliances are not properly secured, they can shift or become damaged, potentially leading to complications such as root resorption or gingivitis [95]. If patients do not follow instructions on how to use appliances correctly, they may not achieve the desired results or may even cause damage to their teeth or gums [96]. All in all, orthodontic treatment can have complications, and appliances can inadvertently contribute to these complications if they are not used correctly or if they are not properly maintained. It is important for patients to follow the instructions of their orthodontist and maintain good oral hygiene throughout treatment to reduce the risk of complications. However, it is important to note that not all patients will experience complications during orthodontic treatment, and most complications can be easily treated or prevented with proper care and attention. It is always a good idea to discuss any concerns or questions you have with your orthodontist, who can help guide you through the treatment process and address any issues that arise.

If compared to what an ideal review assessing orthodontic complications should look like, the number of studies (especially randomized control trials) that we selected for our systematic review and the subsequent meta-analysis can be deemed to be low [42]. However, the fact is that we were very strict in our selection criterion for selecting studies and only chose papers for which the methodological quality was deemed to be fairly moderate to high. We avoided studies conducted during or after the pandemic that analyzed these changes and were specific to COVID-19, because many of the studies available in the online databases were merely scoping reviews or presentations about how the pandemic has affected the incidence of orthodontic treatment-related complications, without substantiated evidence to support the claims. As a result, we believe that more research is required to determine whether complications resulting due to orthodontic treatment modalities have been affected by the incidence of the pandemic.

## 5. Conclusions

There were complications related to orthodontic treatment in all of the studies cited in our systematic analysis, but their severity varied greatly. Gingival mucosa and root resorption, as well as their impacts, were two of the most frequently mentioned periodontal problems in the review. The majority of the issues were determined to arise originally following the start of the treatment plan and to resolve over time, but additional long-term studies are required to confirm the involvement of orthodontic factors in these problems. Two of the most frequently cited periodontal issues in the review were gingival mucosa and root resorption. The majority of the complications were determined to initially arise after the treatment plan had started and to resolve over time, but more extensive, long-term studies are needed to confirm the involvement of an orthodontic component in these issues.

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## References

1. Zhang, M.; Mcgrath, C.; Hägg, U. The impact of malocclusion and its treatment on quality of life: A literature review. *Int. J. Paediatr. Dent.* **2006**, *16*, 381–387. [CrossRef] [PubMed]
2. Dab, S.; Chen, K.; Flores-Mir, C. Short- and long-term potential effects of accelerated osteogenic orthodontic treatment: A systematic review and meta-analysis. *Orthod. Craniofacial Res.* **2019**, *22*, 61–68. [CrossRef] [PubMed]
3. NHS England. Guides for Commissioning Dental Specialties—Orthodontics. 2015. Available online: https://www.england.nhs.uk/commissioning/wp-content/uploads/sites/12/2015/09/guid-comms-orthodontics.pdf (accessed on 26 November 2022).
4. Wang, X.; Bernabe, E.; Pitts, N.; Zheng, S.; Gallagher, J.E. Dental caries thresholds among adolescents in England, Wales, and Northern Ireland, 2013 at 12, and 15 years: Implications for epidemiology and clinical care. *BMC Oral Health* **2021**, *21*, 381–387. [CrossRef]

5. Paes da Silva, S.; Pitchika, V.; Baumert, U.; Wehrbein, H.; Schwestka-Polly, R.; Drescher, D.; Kühnisch, J.; Wichelhaus, A. Oral health-related quality of life in orthodontics: A cross-sectional multicentre study on patients in orthodontic treatment. *Eur. J. Orthod.* **2019**, *42*, 270–280. [CrossRef] [PubMed]
6. Kingsley, C.; Patel, S. Patient-reported outcome measures and patient-reported experience measures. *BJA Educ.* **2017**, *17*, 137–144. [CrossRef]
7. Tsichlaki, A.; O'Brien, K. Do orthodontic research outcomes reflect patient values? A systematic review of randomized controlled trials involving children. *Am. J. Orthod. Dentofac. Orthop.* **2014**, *146*, 279–285. [CrossRef] [PubMed]
8. Lee, R.; Hwang, S.; Lim, H.; Cha, J.; Kim, K.; Chung, C.J. Treatment satisfaction and its influencing factors among adult orthodontic patients. *Am. J. Orthod. Dentofac. Orthop.* **2018**, *153*, 808–817. [CrossRef]
9. Pachêco-Pereira, C.; Pereira, J.R.; Dick, B.D.; Perez, A.; Flores-Mir, C. Factors associated with patient and parent satisfaction after orthodontic treatment: A systematic review. *Am. J. Orthod. Dentofac. Orthop.* **2015**, *148*, 652–659. [CrossRef]
10. Wong, L.; Ryan, F.S.; Christensen, L.R.; Cunningham, S.J. Factors influencing satisfaction with the process of orthodontic treatment in adult patients. *Am. J. Orthod. Dentofac. Orthop.* **2018**, *153*, 362–370. [CrossRef]
11. Hodson, M.; Andrew, S.; Michael Roberts, C. Towards an understanding of PREMS and PROMS in COPD. *Breathe* **2013**, *9*, 358–364. [CrossRef]
12. Bescos, R.; Casas-Agustench, P.; Belfield, L.; Brookes, Z.; Gabaldón, T. Coronavirus disease 2019 (COVID-19): Emerging and future challenges for dental and oral medicine. *J. Dent. Res.* **2020**, *99*, 1113. [CrossRef] [PubMed]
13. Ather, A.; Patel, B.; Ruparel, N.B.; Diogenes, A.; Hargreaves, K.M. Coronavirus disease 19 (COVID-19): Implications for clinical dental care. *J. Endod.* **2020**, *46*, 584–595. [CrossRef]
14. Suri, S.; Vandersluis, Y.R.; Kochhar, A.S.; Bhasin, R.; Abdallah, M. Clinical orthodontic management during the COVID-19 pandemic. *Angle Orthod.* **2020**, *90*, 473–484. [CrossRef] [PubMed]
15. Liberati, A.; Altman, D.G.; Tetzlaff, J.; Mulrow, C.; Gøtzsche, P.C.; Ioannidis, J.P.; Clarke, M.; Devereaux, P.J.; Kleijnen, J.; Moher, D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Med.* **2009**, *6*, e1000100. [CrossRef]
16. Shea, B.J.; Reeves, B.C.; Wells, G.; Thuku, M.; Hamel, C.; Moran, J.; Moher, D.; Tugwell, P.; Welch, V.; Kristjansson, E.; et al. AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* **2017**, *358*, j4008. [CrossRef] [PubMed]
17. Alshahrani, I.; Hameed, M.S.; Syed, S.; Amanullah, M.; Togoo, R.A.; Kaleem, S. Changes in Essential Salivary Parameters in Patients Undergoing Fixed Orthodontic Treatment: A Longitudinal Study. *Niger. J. Clin. Pract.* **2019**, *22*, 707–712. [CrossRef]
18. Aras, I.; Unal, I.; Huniler, G.; Aras, A. Root resorption due to orthodontic treatment using self-ligating and conventional brackets: A cone-beam computed tomography study. *J. Orofac. Orthop.* **2018**, *79*, 181–190. [CrossRef]
19. Bradley, E.; Shelton, A.; Hodge, T.; Morris, D.; Bekker, H.; Fletcher, S.; Barber, S. Patient-reported experience and outcomes from orthodontic treatment. *J. Orthod.* **2020**, *47*, 107–115. [CrossRef]
20. Bucur, S.M.; Iantovics, L.B.; Bud, A.; Bud, E.S.; Cocoș, D.I.; Vlasa, A. Retrospective study regarding orthodontic retention complications in clinical practice. *Appl. Sci.* **2022**, *12*, 273. [CrossRef]
21. Gurdan, Z.; Szalma, J. Evaluation of the success and complication rates of self-drilling orthodontic mini-implants. *Niger. J. Clin. Pract.* **2018**, *21*, 546–552. [CrossRef]
22. Kumar, V.; Singh, P.; Arora, V.K.; Kaur, S.; Sarin, S.; Singh, H. Assessment of Effect of Fixed Orthodontic Treatment on Gingival Health: An Observational Study. *J. Pharm. Bioallied Sci.* **2021**, *13* (Suppl. 1), S425–S428. [CrossRef] [PubMed]
23. Manuelli, M.; Marcolina, M.; Nardi, N.; Bertossi, D.; De Santis, D.; Ricciardi, G.; Luciano, U.; Nocini, R.; Mainardi, A.; Lissoni, A.; et al. Oral mucosal complications in orthodontic treatment. *Minerva Dent. Oral Sci.* **2019**, *68*, 84–88. [CrossRef] [PubMed]
24. Pachevska, A.V.; Filimonov, Y.V.; Filimonov, V.Y.; Dudik, O.P.; Popova, O.I.; Drachuk, N.V.; Kasianenko, D.M.; Biloshitska, A.V.; Istoshyn, V.M. Clinical and laboratory assessment the levelsof oral hygiene, total protein, hydrogen sulfide and nitrogen metabolites in oral fluid in the development of inflammatory complications during orthodontic treatment of children. *Wiadomości Lek.* **2019**, *72*, 744–747. [CrossRef]
25. Puspitasari, Y.; Utama, M.D.; Bachtiar, R.; Achmad, H.; Ilmianti; Yusrini, S.; Novawati, E.; Rusdi, F.J. The Influence of Fixed Orthodontic Treatment on Tooth Discoloration among Dental Students in Makassar, Indonesia. *Ann. Rom. Soc. Cell Biol.* **2021**, *1*, 10720–10728. Available online: https://www.annalsofrscb.ro/index.php/journal/article/view/3844 (accessed on 26 November 2022).
26. Qin, F.; Zhou, Y. The influence of bracket type on the external apical root resorption in class I extraction patients—A retrospective study. *BMC Oral Health* **2019**, *19*, 53. [CrossRef]
27. Rodigues, L.; Shilpa, J.; Bhushan, J.; Sameer, P.; Vikram, G. A questionnaire study to assess and evaluate the common gingival problems faced by patients undergoing fixed orthodontic treatment. *IP Int. J. Maxillofac. Imaging* **2021**, *6*, 101–107. [CrossRef]
28. Fozilov, U.A. Diagnostics and prevention of the development of caries and its complications in children at orthodontic treatment. *J. A Multidiscip. Peer Rev. J.* **2021**, *6*, 276–280. Available online: https://repo.journalnx.com/index.php/nx/article/view/1079 (accessed on 26 November 2022).
29. Uktam, A.F. Prevention of Caries Development During Orthodontic Treatment. *World Bull. Soc. Sci.* **2021**, *3*, 61–66. Available online: https://scholarexpress.net/index.php/wbss/article/view/172 (accessed on 26 November 2022).

30. Von Gorp, G.; Naomi, B.; Ingrid, V.; Guy, W.; Declerck, D. Orthodontic treatment recommendation and expected adverse reactions in patients with a history of dental trauma: A survey among general dentists, paediatric dentists, and orthodontic specialists. *Int. J. Paediatr. Dent.* **2019**, *30*, 360–369. [CrossRef]
31. Currell, S.D.; Liaw, A.; Blackmore Grant, P.D.; Esterman, A.; Nimmo, A. Orthodontic mechanotherapies and their influence on external root resorption: A systematic review. *Am. J. Orthod. Dentofac. Orthop.* **2019**, *155*, 313–329. [CrossRef]
32. Yi, J.; Li, M.; Li, Y.; Li, X.; Zhao, Z. Root resorption during orthodontic treatment with self-ligating or conventional brackets: A systematic review and meta-analysis. *BMC Oral Health* **2016**, *16*, 125. [CrossRef] [PubMed]
33. Alzahawi, K.; Færøvig, E.; Brudvik, P.; Bøe, O.E.; Mavragani, M. Root resorption after leveling with super-elastic and conventional steel arch wires: A prospective study. *Prog. Orthod.* **2014**, *15*, 35. [CrossRef]
34. Roscoe, M.G.; Meira, J.B.; Cattaneo, P.M. Association of orthodontic force system and root resorption: A systematic review. *Am. J. Orthod. Dentofac. Orthop.* **2015**, *147*, 610–626. [CrossRef] [PubMed]
35. Aldeeri, A.; Alhammad, L.; Alduham, A.; Ghassan, W.; Shafshak, S.; Fatani, E. Association of orthodontic clear Aligners with root resorption using three-dimension measurements: A systematic review. *J. Contemp. Dent. Pract.* **2018**, *19*, 1559–1565. [CrossRef]
36. Fang, X.; Qi, R.; Liu, C. Root resorption in orthodontic treatment with clear aligners: A systematic review and meta-analysis. *Orthod. Craniofacial Res.* **2019**, *22*, 259–269. [CrossRef] [PubMed]
37. Gandhi, V.; Mehta, S.; Gauthier, M.; Mu, J.; Kuo, C.; Nanda, R.; Yadav, S. Comparison of external apical root resorption with clear aligners and pre-adjusted edgewise appliances in non-extraction cases: A systematic review and meta-analysis. *Eur. J. Orthod.* **2020**, *43*, 15–24. [CrossRef]
38. Alam, M.K.; Abutayyem, H.; Kanwal, B.A.L.; Shayeb, M. Future of Orthodontics—A Systematic Review and Meta-Analysis on the Emerging Trends in This Field. *J. Clinical Medicine* **2023**, *12*, 532. [CrossRef]
39. Geiger, A.M.; Gorelick, L.; Gwinnett, A.J.; Benson, B.J. Reducing white spot lesions in orthodontic populations with fluoride rinsing. *Am. J. Orthod. Dentofac. Orthop.* **1992**, *101*, 403–407. [CrossRef]
40. Genco, R.J. Current view of risk factors for periodontal diseases. *J. Periodontol.* **1996**, *67*, 1041–1049. [CrossRef]
41. Gorelick, L.; Geiger, A.M.; Gwinnett, A. Incidence of white spot formation after bonding and banding. *Am. J. Orthod.* **1982**, *81*, 93–98. [CrossRef]
42. Harris, E.F. Root resorption during orthodontic therapy. *Semin. Orthod.* **2000**, *6*, 183–194. [CrossRef]
43. Hwang, J.Y.; Tee, C.H.; Huang, A.T.; Taft, L. Effectiveness of thera-bite wafers in reducing pain. *J. Clin. Orthod.* **1994**, *28*, 291–292.
44. Ketcham, A.H. A progress report of an investigation of apical root resorption of vital permanent teeth. *Int. J. Orthod. Oral Surg. Radiogr.* **1929**, *15*, 310–328. [CrossRef]
45. Killiany, D.M. Root resorption caused by orthodontic treatment: Review of literature from 1998 to 2001 for evidence. *Prog. Orthod.* **2002**, *3*, 2–5. [CrossRef]
46. Kremenak, C.R.; Kinser, D.D.; Harman, H.A.; Menard, C.C.; Jakobsen, J.R. Orthodontic risk factors for temporomandibular disorders (TMD). I: Premolar extractions. *Am. J. Orthod. Dentofac. Orthop.* **1992**, *101*, 13–20. [CrossRef] [PubMed]
47. Kremenak, C.R.; Kinser, D.D.; Meicher, T.J.; Wright, G.R.; Harrison, S.D.; Ziaja, R.R.; Harman, H.A.; Ordahl, J.N.; Demro, J.G.; Menard, C.C.; et al. Orthodontics as a risk factor for temporomandibular disorders (TMD). II. *Am. J. Orthod. Dentofac. Orthop.* **1992**, *101*, 21–27. [CrossRef]
48. Krishnan, V. Critical issues concerning root resorption: A contemporary review. *World J. Orthod.* **2005**, *6*, 30–40.
49. Krishnan, V.; Davidovitch, Z. Biological mechanisms of tooth movements, 2nd edition. *J. Indian Orthod. Soc.* **2015**, *49*, 126. [CrossRef]
50. Kvinnsland, S.; Heyeraas, K.; Øfjord, E.S. Effect of experimental tooth movement on periodontal and pulpal blood flow. *Eur. J. Orthod.* **1989**, *11*, 200–205. [CrossRef]
51. Steen Law, S.L.; Southard, K.A.; Law, A.S.; Logan, H.L.; Jakobsen, J.R. An evaluation of preoperative ibuprofen for treatment of pain associated with orthodontic separator placement. *Am. J. Orthod. Dentofac. Orthop.* **2000**, *118*, 629–635. [CrossRef]
52. Levander, E.; Malmgren, O.; Eliasson, S. Evaluation of root resorption in relation to two orthodontic treatment regimes. A clinical experimental study. *Eur. J. Orthod.* **1994**, *16*, 223–228. [CrossRef] [PubMed]
53. Levander, E. Early radiographic diagnosis of apical root resorption during orthodontic treatment: A study of maxillary incisors. *Eur. J. Orthod.* **1998**, *20*, 57–63. [CrossRef] [PubMed]
54. Lew, K.K. Attitudes and perceptions of adults towards orthodontic treatment in an Asian community. *Community Dent. Oral Epidemiol.* **1993**, *21*, 31–35. [CrossRef] [PubMed]
55. Linge, L.; Linge, B.O. Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment. *Am. J. Orthod. Dentofac. Orthop.* **1991**, *99*, 35–43. [CrossRef]
56. Malmgren, O.; Goldson, L.; Hill, C.; Orwin, A.; Petrini, L.; Lundberg, M. Root resorption after orthodontic treatment of traumatized teeth. *Am. J. Orthod.* **1982**, *82*, 487–491. [CrossRef] [PubMed]
57. Mirabella, A.; Årtun, J. Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients. *Am. J. Orthod. Dentofac. Orthop.* **1995**, *108*, 48–55. [CrossRef]
58. Mohlin, B.; Axelsson, S.; Paulin, G.; Pietilä, T.; Bondemark, L.; Brattström, V.; Hansen, K.; Holm, A. TMD in relation to Malocclusion and orthodontic treatment. *Angle Orthod.* **2007**, *77*, 542–548. [CrossRef]
59. Ngan, P.; Kess, B.; Wilson, S. Perception of discomfort by patients undergoing orthodontic treatment. *Am. J. Orthod. Dentofac. Orthop.* **1989**, *96*, 47–53. [CrossRef]

60. Ngan, P.; Wilson, S.; Shanfeld, J.; Amini, H. The effect of ibuprofen on the level of discomfort inpatients undergoing orthodontic treatment. *Am. J. Orthod. Dentofac. Orthop.* **1994**, *106*, 88–95. [CrossRef]
61. Øgaard, B.; Rølla, G.; Arends, J. Orthodontic appliances and enamel demineralization. *Am. J. Orthod. Dentofac. Orthop.* **1988**, *94*, 68–73. [CrossRef]
62. Øgaard, B.; Rølla, G.; Arends, J.; Ten Cate, J. Orthodontic appliances and enamel demineralization Part 2. Prevention and treatment of lesions. *Am. J. Orthod. Dentofac. Orthop.* **1988**, *94*, 123–128. [CrossRef] [PubMed]
63. Osterberg, T.; Carlsson, G.E. Symptoms and signs of mandibular dysfunction in 70-year-old men and women in Gothenburg, Sweden. *Community Dent. Oral Epidemiol.* **1979**, *7*, 315–321. [CrossRef]
64. Parker, W.S. Root resorption—Long-term outcome. *Am. J. Orthod. Dentofac. Orthop.* **1997**, *112*, 119–123. [CrossRef] [PubMed]
65. Lucchese, A.; Bonini, C.; Noviello, M.; Lupo Stanghellini, M.T.; Greco, R.; Peccatori, J.; Biella, A.; Tassi, E.; Beretta, V.; Ciceri, F.; et al. The Effect of Removable Orthodontic Appliances on Oral Microbiota: A Systematic Review. *Appl. Sci.* **2021**, *11*, 2881. [CrossRef]
66. Li, X.; Tang, Y.; Chen, Y. Interventions for pain during fixed orthodontic appliance therapy. *Angle Orthod.* **2010**, *80*, 925–932. [CrossRef]
67. Polat, Ö. Pain and discomfort after orthodontic appointments. *Semin. Orthod.* **2007**, *13*, 292–300. [CrossRef]
68. Pullinger, A.G.; Seligman, D.A.; Solberg, W.K. Temporomandibular disorders. Part I: Functional status, dentomorphologic features, and sex differences in a nonpatient population. *J. Prosthet. Dent.* **1988**, *59*, 228–235. [CrossRef]
69. Pullinger, A.; Seligman, D.; Gornbein, J. A multiple logistic regression analysis of the risk and relative odds of Temporomandibular disorders as a function of common occlusal features. *J. Dent. Res.* **1993**, *72*, 968–979. [CrossRef]
70. Rendell, J.K.; Norton, L.A.; Gay, T. Orthodontic treatment and temporomandibular joint disorders. *Am. J. Orthod. Dentofac. Orthop.* **1992**, *101*, 84–87. [CrossRef]
71. Sadowsky, C.; BeGole, E.A. Long-term status of temporomandibular joint function and functional occlusion after orthodontic treatment. *Am. J. Orthod.* **1980**, *78*, 201–212. [CrossRef]
72. Priti, M.; Adinegara, A.; Laxminarayan, K.; Raffaella, C.; Palna, K. Treatment of dental and orthodontic complications in thalassaemia. *Cochrane Database Syst. Rev.* **2023**, *1*, 1–10. [CrossRef]
73. Ma, Z.; Zhu, Y.; Zhan, Y.; Zhang, Y.; Abdelrehem, A.; Wang, B.; Yang, C. Periosteum coverage versus collagen-membrane coverage in periodontally accelerated osteogenic orthodontics: A randomized controlled clinical trial in class II and class III malocclusions. *BMC Oral Health* **2022**, *22*. [CrossRef] [PubMed]
74. Van, T.; Soyeon, K.; Jaeheon, K.; Joo, L.; Young-Seok, P. Revisiting the Complications of Orthodontic Miniscrew. *BioMed Res. Int.* **2022**, *2022*, 8720412. [CrossRef]
75. Michele, I.A.; Giuseppina, M.; Stefania, C.; Maria, F.; Pasquale, A.; Merigrazia, C.; Fabio, P.; Assunta, P.; Irene, F.; Chiara, P.; et al. Tooth Complications after Orthodontic Miniscrews Insertion. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1562. [CrossRef]
76. Chaniotis, A.; Chanioti, A. Long-term complications of previously successful regenerative endodontic procedures after orthodontic movement: A report of 3 different complications after 4, 8, and 11 years. *J. Endod.* **2022**, *48*, 951–960. [CrossRef] [PubMed]
77. Montasser, M.A.; Scribante, A. Root injury during Interradicular insertion is the most common complication associated with orthodontic Miniscrews. *J. Evid. Based Dent. Pract.* **2022**, *22*, 101688. [CrossRef] [PubMed]
78. Rahimipour, K.; Mousavi, R.; Behnaz, M.; Dalaie, K.; Farahnaki, A.; Davoodi, N.S. Invisalign orthodontic system: Treatment efficacy, complications, patients' attitude. *Orthod. Forum* **2020**, *15*, 108–123. [CrossRef]
79. Habegger, M.; Renkema, A.; Bronkhorst, E.; Fudalej, P.S.; Katsaros, C. A survey of general dentists regarding orthodontic retention procedures. *Eur. J. Orthod.* **2016**, *39*, 69–75. [CrossRef]
80. Chambers, D.W.; Zitterkopf, J.G. How people make decisions about whether or not to seek orthodontic care: Upstream in the treatment chain. *Am. J. Orthod. Dentofac. Orthop.* **2019**, *155*, 826–831. [CrossRef]
81. Kučera, J.; Littlewood, S.J.; Marek, I. Fixed retention: Pitfalls and complications. *Br. Dent. J.* **2021**, *230*, 703–708. [CrossRef]
82. Akbari, M.; Prabhu, R.; Khanna, S.; Turner, M.D. Resident commentary: Is there a significant difference in relapse and complication rate of surgically assisted rapid palatal expansion using tooth-borne, bone-borne, and orthodontic mini-implant-Borne appliances (Ploder et al, 2020)? *J. Oral Maxillofac. Surg.* **2021**, *79*, e1–e3. [CrossRef] [PubMed]
83. Van Gorp, G.; Bormans, N.; Vanham, I.; Willems, G.; Declerck, D. Knowledge of orthodontic treatment approach of traumatized teeth by a group of Belgian general dentists, pediatric dentists, and orthodontists. *Dent. Traumatol.* **2019**, *35*, 233–240. [CrossRef] [PubMed]
84. Padmos, J.A.; Fudalej, P.S.; Renkema, A.M. Epidemiologic study of orthodontic retention procedures. *Am. J. Orthod. Dentofac. Orthop.* **2018**, *153*, 496–504. [CrossRef]
85. Mohaghegh, S.; Soleimani, M.; Kouhestani, F.; Motamedian, S.R. The effect of single/multiple micro-osteoperforation on the rate of orthodontic tooth movement and its possible complications: A systematic review and meta-analysis. *Int. Orthod.* **2021**, *19*, 183–196. [CrossRef] [PubMed]
86. Alencar, L.B.; Sousa, S.C.; Silva, I.L.; Araújo, V.F.; Oliveira, E.B.; Fonseca-Filho, D.T.; Macena, M.C.; Fonseca, F.R. Allergic reactions in orthodontic patients: A review. *Int. J. Odontostomatol.* **2021**, *15*, 132–136. [CrossRef]
87. Madurantakam, P.; Kumar, S. Are there more adverse effects with lingual orthodontics? *Evid.-Based Dent.* **2017**, *18*, 101–102. [CrossRef]

88. Šimunović, L.; Blagec, T.; Vrankić, A.; Meštrović, S. Color Stability of Orthodontic Ceramic Brackets and Adhesives in Potentially Staining Beverages—In Vitro Study. *Dent. J.* **2022**, *10*, 115. [CrossRef]
89. Yap, J. Measuring what really matters—Revisiting health system performance measurement. *Int. J. Integr. Care* **2022**, *22*, 108. [CrossRef]
90. Yong, J.; Gröger, S.; Von Bremen, J.; Meyle, J.; Ruf, S. PD-L1, a potential Immunomodulator linking immunology and Orthodontically induced inflammatory root resorption (OIIRR): Friend or foe? *Int. J. Mol. Sci.* **2022**, *23*, 11405. [CrossRef]
91. Msallam, F.A.; Grawish, M.E.; Hafez, A.M.; Abdelnaby, Y.L. Decalcification prevention around orthodontic brackets bonded to bleached enamel using different topical agents. *Prog. Orthod.* **2017**, *18*, 15. [CrossRef]
92. Joss-Vassalli, I.; Grebenstein, C.; Topouzelis, N.; Sculean, A.; Katsaros, C. Orthodontic therapy and gingival recession: A systematic review. *Orthod. Craniofacial Res.* **2010**, *13*, 127–141. [CrossRef] [PubMed]
93. Gokce, G. Complications and risks of orthodontic treatment. *Dent. Med. J. Rev.* **2021**, *3*, 38–51. Available online: https://dergipark.org.tr/tr/pub/dmj/issue/63407/910688 (accessed on 26 November 2022).
94. Wishney, M. Potential risks of orthodontic therapy: A critical review and conceptual framework. *Aust. Dent. J.* **2017**, *62*, 86–96. [CrossRef]
95. Kurniawan, F.K.; Roestamadji, R.I.; Takahashi, N.; Tedjosasongko, U.; Narmada, I.B.; Surboyo, M.D.; Diyatri, I. Oral microbiome profiles and inflammation in pregnant women who used orthodontic appliances. *Dent. J.* **2022**, *10*, 118. [CrossRef]
96. Perkowski, K.; Baltaza, W.; Conn, D.B.; Marczyńska-Stolarek, M.; Chomicz, L. Examination of oral biofilm microbiota in patients using fixed orthodontic appliances in order to prevent risk factors for health complications. *Ann. Agric. Environ. Med.* **2019**, *26*, 231–235. [CrossRef] [PubMed]