Original Article

Bracket positioning have an impact on smile arc protection – a systematic review and meta-analysis

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ABSTRACT

Background and objectives

The available literature concerning bracket positioning and its relationship with smile arc protection (SAP) lacks adequate methodology and significant sample sizes. The majority of the literature consists of case reports with small sample sizes, cross-sectional studies, in vitro studies, literature reviews, and systematic reviews. Thus, the principal objective of this study was to assess the existing literature on bracket positioning and its influence on SAP, and to amalgamate the data from various studies to generate a comprehensive analysis of the effectiveness of bracket positioning in achieving SAP.

Selection criteria and search protocol: Databases of Cochrane Library, EMBASE, PubMed, MEDLINE, Scopus and Google Scholar were searched using predetermined selection criteria.

Analysis protocol: The Newcastle-Ottawa Scale (NOS) was employed for the evaluation of bias in the studies included in the review.

Results

Three relevant studies were considered for inclusion in the review. Odds ratio (OR) of 0.53 with a 95% confidence interval (CI) of 0.33 to 0.85, and risk ratio (RR) of 0.64 with a 95% CI of 0.45 to 0.90 were obtained after meta-analysis, indicating a significant impact of bracket positioning on SAP. The test for overall effect also demonstrated a statistically significant effect of bracket positioning on SAP.

Conclusion and further implications: The findings suggest that bracket positioning has a noticeable impact on SAP, with decreased odds or relative risk of protection associated with improper positioning. However, the level of heterogeneity between the studies suggests that further research is needed to confirm these findings. The limitations of the study include the small number of studies under review and the variability in study designs and methods.

Registration and protocol: Registration was done in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards [CRD42023407270]. The research protocol was created to meet the goals and was properly filed with PROSPERO.

Keywords

Orthodontic bracket; smile arc protection; Orthodontic aesthetics; Orthodontic therapy

INTRODUCTION

Brackets are one of the most commonly used orthodontic appliances in the correction of misaligned teeth and jaws. [1] Brackets consist of small metal or ceramic squares that are bonded to the tooth surface and connected to an archwire with elastic ligatures. The archwire is responsible

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for exerting force on the brackets, which in turn applies pressure to the teeth, gradually moving them into the desired position. [2]

Brackets can be made from a variety of materials, including stainless steel, ceramic, and plastic. [3] Stainless steel brackets are the most commonly used and are highly durable, while ceramic brackets are more aesthetic but can be more brittle and prone to breaking. [4] Plastic brackets are rarely used in orthodontics due to their low durability. The usage of brackets is widespread due to their versatility and effectiveness. They can be used to correct a wide range of orthodontic issues, including crowding, spacing, overbite, underbite, and crossbite. [5] The duration of treatment with brackets depends on the complexity of the orthodontic case but typically ranges from 1-3 years. Studies have shown that bracket-based orthodontic treatment is highly effective in achieving the desired orthodontic outcomes. Brackets have been found to be more effective than other orthodontic treatment modalities, such as removable appliances or aligners, in correcting moderate to severe malocclusions. [6] Additionally, bracket-based treatment has been found to result in more predictable outcomes and fewer relapses compared to other modalities. [7]

SAP is a concept in orthodontics that refers to the maintenance of a smooth, symmetric and continuous curvature of the dental arch during orthodontic treatment. [8] The ideal smile arc is achieved when the curvature of the upper incisors harmonizes with the lower lip line. The SAP is crucial as it determines the overall aesthetics of the patient's face and smile. [9] A misaligned or broken smile arc can result in a less appealing smile, negatively impacting the patient's self-confidence and quality of life. [10] Orthodontic treatment aims to correct malocclusion, improve occlusal function, and enhance facial aesthetics, including the SAP. [11] Orthodontic appliances such as braces, aligners, and other devices are used to reposition teeth to achieve an ideal SAP. [12] Treatment planning for SAP should include a comprehensive evaluation of the dental and facial structures, as well as the patient's soft tissue profile. [13-16]

The current literature on bracket positioning with respect to SAP lacks studies with substantial sample sizes and appropriate methodology. [14] Most of the studies available are case reports with small sample sizes, cross-sectional studies, in vitro studies, literature reviews, and systematic reviews. The lack of high-quality evidence makes it difficult to draw conclusive statements about the efficacy of bracket positioning in achieving optimal SAP. This indicates that there is a need for more well-designed, randomized controlled trials with larger sample sizes to provide more reliable and robust evidence regarding the impact of bracket positioning on SAP. The current literature gaps highlight the need for further research in this area to guide clinical decision-making and improve orthodontic treatment outcomes. Therefore, the primary aim of this study was to evaluate the existing literature on bracket positioning and its impact on SAP and synthesize the evidence from different studies to provide a comprehensive analysis of the effectiveness of bracket positioning in achieving SAP. We also aimed to provide a clear understanding of the benefits of bracket positioning and its impact on SAP by means of this investigation, which could help inform clinical practice and improve patient outcomes.

MATERIALS AND METHODS

Review design and protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines are a widely accepted framework for conducting and reporting systematic reviews and meta-analyses. [17-18] With respect to our investigation, the PRISMA guidelines were closely followed to ensure a rigorous and transparent process. The review team used the PRISMA checklist as a guide for the inclusion and exclusion criteria, data extraction, and quality assessment of the included studies. The use of PRISMA ensured that the review was comprehensive, transparent, and replicable. The PRISMA flow diagram was also used to illustrate the selection process of studies (Figure 1). By adhering to the PRISMA guidelines, the study was able to produce high-quality results and minimize the risk of bias.

Study selection strategy

The PICOS (Population, Intervention, Comparison, Outcome, and Study design) strategy was used for this systematic review and the subsequent meta-analysis. The study aimed to identify the impact of bracket positioning on SAP. The population of interest for

this review was individuals undergoing orthodontic treatment with brackets. The intervention of interest was different bracket positioning techniques. The comparison group was individuals with brackets placed using conventional techniques. The primary outcome was the impact on the smile arc, which is the natural curvature of the upper and lower teeth when smiling. The study design of interest was randomized controlled trials (RCTs), prospective studies, retrospective studies and case-control studies that reported outcomes related to smile arc. Studies with less substantial sample sizes, case reports with less than 10 individuals, cross-sectional studies, in vitro studies, literature reviews and systematic reviews were excluded from the analysis. The PICOS strategy allowed for a focused and systematic approach to identify relevant studies for the review and ensured that the research question was clearly defined and specific.

Protocol for database search

For the systematic review and meta-analysis on bracket positioning and its impact on SAP, a comprehensive literature search was conducted across various databases including PubMed, MEDLINE, Scopus, Google Scholar, Cochrane Library and EMBASE. For the PubMed database, we used Boolean operators such as "AND", "OR" and "NOT" along with MeSH keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a thorough search. The search was performed using a combination of these terms to ensure that all relevant articles were included in the search. In addition, we also used filters such as publication date, study design and language to narrow down the search results to only include articles that were relevant to our study. The use of Boolean operators and MeSH keywords allowed us to identify relevant studies in a systematic and comprehensive manner.

Similar to PubMed, we used Boolean operators such as "AND", "OR" and "NOT" along with MeSH keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a comprehensive search of the MEDLINE database.

In the Scopus database, we used Boolean operators such as "AND", "OR" and "NOT" along with keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a thorough search.

In Google Scholar, we used Boolean operators such as "AND", "OR" and "NOT" along with keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a broad search.

In the Cochrane Library, we used Boolean operators such as "AND", "OR" and "NOT" along with keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a comprehensive search.

In the EMBASE database, we used Boolean operators such as "AND", "OR" and "NOT" along with keywords such as "Bracket Positioning", "SAP", "Orthodontics", "Dental Appliances" and "Malocclusion" to conduct a thorough search.

Criteria for selecting studies

For our study, a thorough set of inclusion and exclusion criteria were established to ensure that only high-quality studies were selected for analysis. Studies that met the following inclusion criteria were selected: 1) randomized controlled trials, 2) prospective or retrospective cohort studies, and 3) case-control studies. Studies were included if they evaluated the effect of bracket positioning on SAP in patients undergoing orthodontic treatment. However, studies with less substantial sample sizes, case reports with less than 10 individuals, cross-sectional studies, in vitro studies, literature reviews, and systematic reviews were not included. Exclusion criteria also included studies that did not report sufficient data for analysis and studies that were not published in English. These criteria were established to ensure that only studies with sufficient sample sizes and appropriate study designs were included while minimizing the risk of bias in the analysis.

Reviewer team protocol

Three reviewers, who were all orthodontic specialists, were involved in the review process. Each reviewer was assigned specific domains, and were tasked with evaluating and assessing the quality of the included studies. The domains included study design, sample size, participant characteristics, intervention/exposure, outcomes, statistical analysis, and risk of bias. To

ensure consistency and accuracy, the reviewers underwent training on how to assess the studies using the Newcastle-Ottawa Scale (NOS). They also discussed any discrepancies in their evaluations and worked collaboratively to reach a consensus. The reviewers followed a strict procedure for the selection and evaluation of studies. First, they independently screened the titles and abstracts of the identified studies to determine their eligibility based on the predefined inclusion and exclusion criteria. Then, they independently assessed the full-text articles of the selected studies and evaluated their quality based on the relevant domains using the appropriate tools.

In cases where there were discrepancies or uncertainties, the reviewers discussed and resolved them through consensus or with the involvement of a fourth reviewer. The final decision on the inclusion of the studies was made based on the agreement of all three reviewers. Overall, the multiple reviewer strategy helped ensure the quality and consistency of the review process and the validity of the findings. It also helped minimize the potential for errors and biases in the selection and evaluation of the studies.

Bias evaluation protocol

For the systematic review and meta-analysis on the impact of bracket positioning on SAP, the bias assessment of the included studies was performed using the NOS. [19-20] The NOS is a widely used tool for assessing the quality of non-randomized studies, particularly observational studies. The scale assesses the studies in three domains, including the selection of the study groups, comparability of the groups, and ascertainment of the exposure or outcome. Each domain has several criteria, and the studies are assigned a score based on the fulfilment of these criteria. The studies with a score of 6 or more out of 9 are considered to have a low risk of bias, while those with a score of 5 or less are considered to have a high risk of bias. The bias assessment was performed independently by two reviewers, and any disagreements were resolved through discussion or with the involvement of a third reviewer. The assessment of bias was used to inform the sensitivity analysis and subgroup analysis of the meta-analysis, as well as the overall interpretation of the study results.

Protocol for meta-analysis

For the statistical analysis of the studies included in our review, RevMan 5 software was used. The software was utilized to generate forest plots for OR and RR, based on the overall impact of brackets used on the total participants of the respective studies. The forest plots were generated assuming a 95% CI and a fixed effects model. The software allowed for the synthesis of data from multiple studies to produce a summary estimate of the overall effect of bracket positioning on SAP. The generated forest plots helped in visually presenting the results of the meta-analysis, showing the effect size and precision of each study included in the analysis, and indicating whether the results were statistically significant. Overall, the RevMan 5 software played a crucial role in the statistical analysis of the systematic review and meta-analysis, providing valuable insights into the impact of bracket positioning on SAP.

RESULTS

At the end of the search protocol implementation, three clinical studies [21-23] were considered for inclusion in our review. Figure 2 provides an evaluation of the risk of bias in the included studies using the NOS. The scale assesses the studies based on multiple domains, including representativeness of the exposed cohort, study design quality, selection of the non-exposed cohort, ascertainment of exposure, comparability of cohorts, assessment of outcome, length of follow-up, statistical analysis adequacy, and control of additional factors. Based on the table, the studies included in the analysis had a low to unclear risk of bias across most domains. The exception was the Christou et al. study [21], which had a high risk of bias in the study design quality domain and an unclear risk of bias in multiple domains, including representativeness of the exposed cohort, adequacy of statistical analysis, and assessment of additional factors. The Yunus et al. [22] and Shook et al. [23] studies had low to unclear risk of bias across all domains.

Table 1 provides information about the three studies examining the relationship between bracket positioning and SAP. The table includes the author's ID, year of publication, region where the study was conducted, sample size (n), gender information, and age range of participants. The first study, conducted by Christou et al. [21] in 2020 in

the USA, had a sample size of 58 participants. The study included 19 males and the age range of participants was 12-30 years. The second study, conducted by F. Yunus et al. [22] in 2020 in India, had a sample size of 30 participants. However, no information was provided regarding the gender of the participants. The age range of participants was 15-24 years. The third study, conducted by Shook et al. [23] in 2016 in the USA, had a larger sample size of 84 participants. The study included 41 males and the mean age of participants was 15.19 years. It is important to note that this study provides the mean age of participants instead of the age range.

Information about the design, objectives, groups, bracket measurements, and inferences assessed in three studies examining the relationship between bracket positioning and SAP are likewise provided in Table 2. Christou et al. [21] was a case-control study that aimed to compare the effectiveness of Invisalign and fixed appliances in maintaining a smile arc. The study included two groups: an Invisalign group and a fixed appliance group. The bracket measurements for the fixed appliance group were 0.22-inch slots prepared using the Edgewise technique. The study found that the fixed appliance group performed better across six variables as compared to two for Invisalign in relation to overall smile scores. F. Yunus et al. [22], was a prospective study that aimed to assess the effectiveness of different bracket positioning systems in maintaining an ideal and flat smile arc on a pre-treatment and post-treatment basis. The study included two groups: optimal smile arc and flat arc. The bracket measurements for both groups were 0.22-inch slots of McLaughlin, Bennett and Trevisi bracket positioning systems. The study found that optimal smile arc maintenance was significantly achieved in the flat arc group as indicated by the intrusion observed in maxillary canines during the post-alignment period. However, the ideal smile group's arc was maintained throughout. Shook et al. [23], was a retrospective study that aimed to compare the effectiveness of conventional and self-ligating brackets in maintaining a smile arc. The study included two groups: conventional brackets and Damon self-ligating brackets. The bracket measurements for both groups were 0.22-inch slots prepared using the Edgewise technique. The study found no significant differences between the two groups as observed through the analysis of the maxillary arch width and changes related to the buccal corridor.

Figure 3 represents the forest plot that was generated to examine the noticeable versus the negligible impact of bracket positioning on SAP, as indicated by an OR of 0.53 with a 95% CI of 0.33 to 0.85. The forest plot also displayed the results of the statistical analyses of heterogeneity and overall effect. The heterogeneity test showed a chi-squared value of 3.76 with two degrees of freedom (df) and a corresponding p-value of 0.15. Additionally, the I-squared (I^2) statistic was calculated to be 47%, which suggests moderate heterogeneity between the studies. Moreover, the test for overall effect revealed a Z-score of 2.61 with a corresponding p-value of 0.009, indicating that there is a statistically significant effect of bracket positioning on SAP. Overall, these results suggest that bracket positioning has a noticeable impact on SAP, with decreased odds of protection associated with improper positioning.

The forest plot represented in Figure 4 was obtained by statistical analysis to examine the noticeable versus the negligible impact of bracket positioning on SAP, as measured by a RR of 0.64 with a 95% CI of 0.45 to 0.90. The forest plot also displayed the results of the statistical analyses of heterogeneity and overall effect. The heterogeneity test showed a chi-squared value of 2.83 with two degrees of freedom (df) and a corresponding p-value of 0.24. Additionally, the I-squared (I^2) statistic was calculated to be 29%, which suggests low heterogeneity between the studies. Furthermore, the test for overall effect revealed a Z-score of 2.57 with a corresponding p-value of 0.01, indicating that there is a statistically significant effect of bracket positioning on SAP. These results suggest that bracket positioning has a noticeable impact on SAP, with a decreased relative risk of protection associated with improper positioning. However, the low level of heterogeneity between the studies suggests that the findings are consistent and reliable.

Overall, the forest plot analysis provides evidence to support the hypothesis that bracket positioning has a noticeable impact on SAP. The statistically significant overall effect and the low level of heterogeneity between the studies increase the confidence in the validity of the findings. Nonetheless, additional research with larger sample sizes and more diverse populations may be necessary to generalize the results to broader populations.

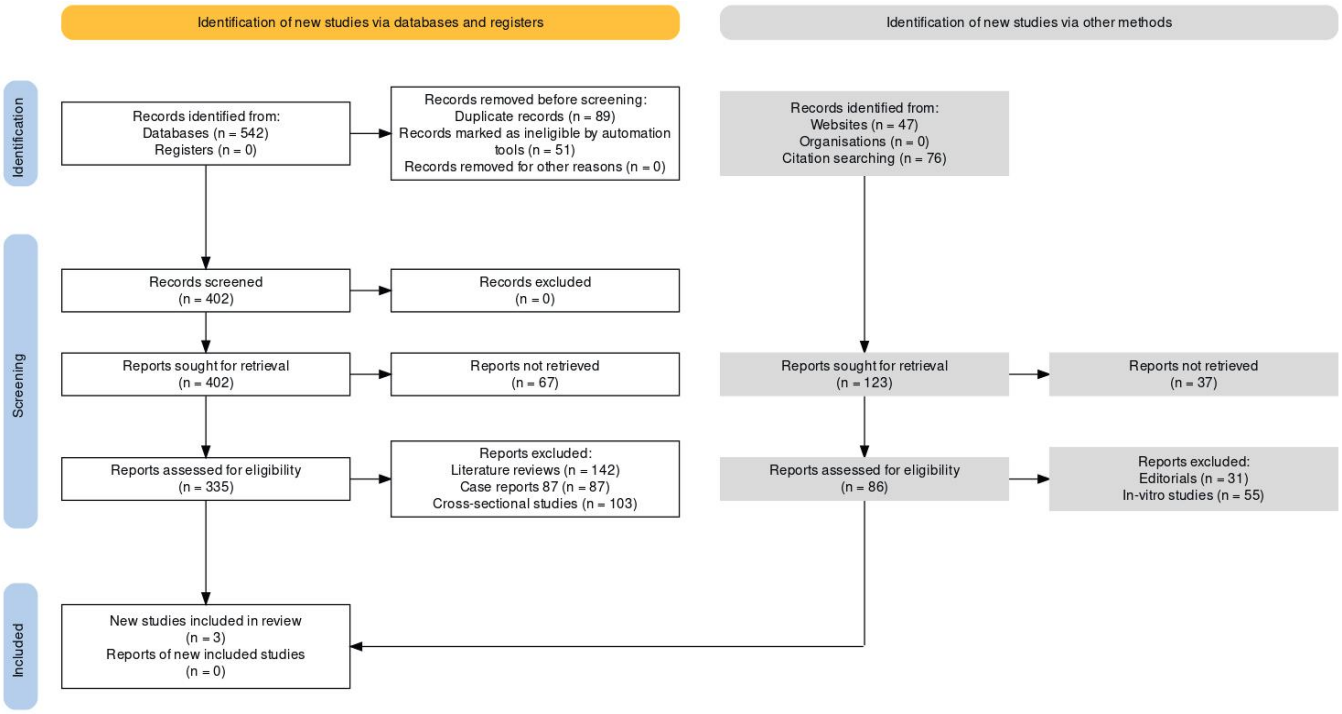

Figure 1: Flowchart representing the study selection framework for this review using the PRISMA guidelines

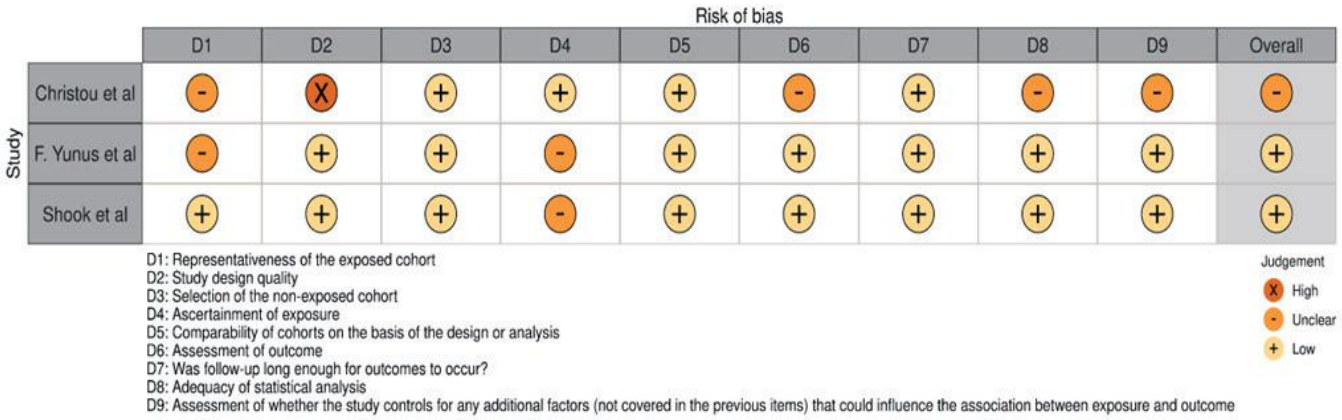

Figure 2: Risk of bias assessment of the included studies in this review

Table 1: Studies included in the review and their demographic characteristics

Author ID	*Year*	*Region*	*Sample size (n)*	*Gender information*	*Age range (in years)*
Christou et al. [21]	2020	USA	58	19 males	12-30
F. Yunus et al. [22]	2020	India	30	Unspecified	15-24
Shook et al. [23]	2016	USA	84	41 males	15.19 (mean)

Table 2: Technical characteristics pertaining to objectives, bracket positioning used, groups and inferences observed in the selected papers

Author ID	*Design*	*Objectives*	*Groups*	*Bracket measurements*	*Inference assessed*
Christou et al. [21]	Case-control	Comparison between Invisalign and fixed appliances pertaining to smile arc maintenance	Two (Invisalign and fixed appliance group)	0.22-inch slots prepared using the Edgewise technique	Bracket usage performed better across six variables as compared to two for Invisalign in relation to overall smile scores
F. Yunus et al. [22]	Prospective	Assessment of different bracket positioning systems in ideal and flat smile arcs on a pre-treatment and post-treatment basis	Two (optimal smile arc and flat arc)	0.22-inch slots of McLaughlin, Bennett and Trevisi Bracket Positioning systems	Optimal smile arc maintenance was significantly achieved in the flat arc group as indicated by the intrusion observed in maxillary canines during the post-alignment period; the ideal smile arc group's arc was maintained throughout
Shook et al. [23]	Retrospective	Comparison between conventional and self-ligating brackets pertaining to smile arc maintenance	Two (conventional brackets and Damon self-ligating brackets)	0.22-inch slots prepared using the Edgewise technique for both bracket groups	No significant differences were observed between the two groups as demonstrated through the analysis of the maxillary arch width and changes related to the buccal corridor

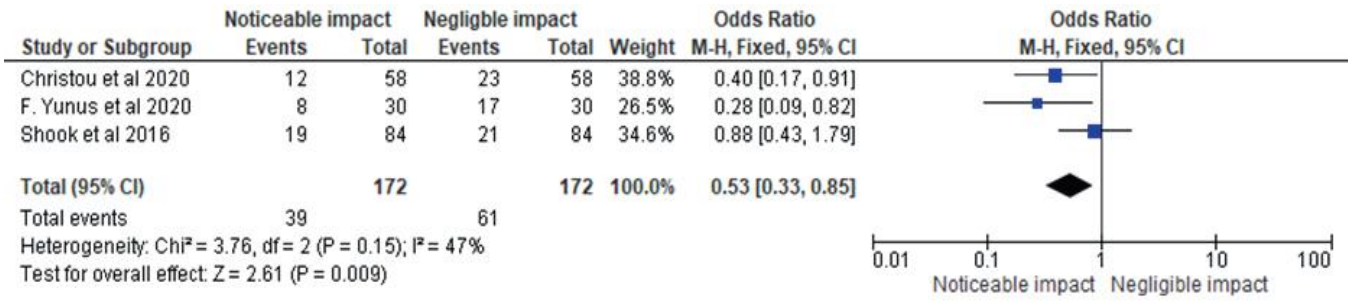

Figure 3: OR statistics related to the impact of different bracket positioning systems on SAP represented on a forest plot

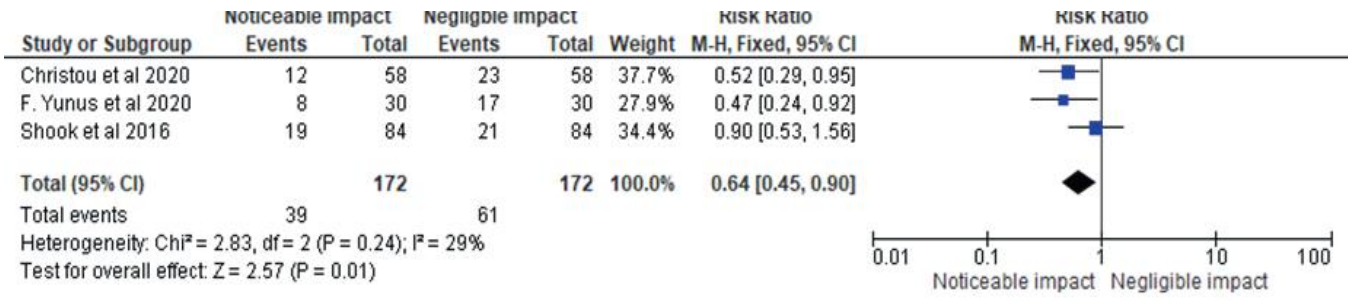

Figure 4: RR statistics related to the impact of different bracket positioning systems on SAP represented on a forest plot

DISCUSSION

The present study provides a comprehensive analysis of the relationship between bracket positioning and SAP. The results of the statistical analyses indicate a noticeable impact of bracket positioning on SAP, with decreased odds of protection associated with improper positioning. The findings of this study fill a significant gap in the literature by synthesizing and comparing the results of three studies that examined the impact of bracket positioning on SAP. This study provides a better understanding of the relationship between bracket positioning and SAP, which could have important implications for orthodontic treatment planning and decision-making.

The results of this study suggest that proper bracket positioning is crucial for maintaining a desirable smile arc and that bracket positioning should be considered during orthodontic treatment planning. In the future, this study could serve as a basis for further research to explore the effect of bracket positioning on other outcomes such as functional occlusion, patient satisfaction, and treatment duration. The study findings also suggest that improper bracket positioning has a noticeable impact on SAP, which could potentially affect the overall outcome of orthodontic treatment. The results provide valuable insights into the importance of proper bracket positioning and highlight the need for continued research on this topic.

The study's emphasis on high-quality studies and the exclusion of those with less substantial sample sizes, case reports with less than 10 individuals, in vitro studies, literature reviews and systematic reviews, adds value to the existing literature by filling in gaps in knowledge with rigorous and reliable research. The significant impact of this study on clinical practice is that orthodontists can utilize the findings to improve their practice by ensuring proper bracket positioning. This can lead to better patient outcomes, increased patient satisfaction, and reduced overall treatment time and cost. In the future, the results of this study could lead to the development of standardized protocols for bracket positioning in orthodontic treatment, to further enhance treatment outcomes and patient satisfaction. Overall, the present study has contributed significantly to the existing literature on bracket positioning and its impact on SAP. The findings provide valuable insights into the importance of proper bracket positioning and highlight the need for continued research in this area to improve the quality of orthodontic treatment.

More than 50 years ago, prosthodontists first noted how important a symmetrical curve of the maxillary front incisal margins was in producing a youthful and attractive aesthetic look. [24] Although physicians typically prefer the term SAP, orthodontic specialists have historically referred to the "curved smile line" when discussing smile aesthetics. [25] Early 3D management of the upper anterior tooth locations has become crucial in preventing the incisor flare and flattening of the smile arc often associated with crowding relief due to the steadily rising prevalence of non-extraction treatment. [26] For numerous clinicians, the most aesthetically appealing and youthful proportion for a posed smile when judged in normal head posture combines full enamel display of the upper anterior teeth with 1-1.5mm of gingival retraction. [27] The mechanics pertaining to SAP can be further assisted when more incisor retroclination is desired by 180° flipping the upper anterior brackets, which will create active lingual crown torque in the slot when used with dimensional archwires. [28] Well-designed incisor brackets retain their tip and in-out geometry even when they are inverted. [29] Unfortunately, even the highest-quality appliances are unable to deliver consistent expression of their stated torque prescriptions due to a number of common factors, including oversized bracket slots, inconsistent slot geometries (caused by poor manufacturing tolerance control), excessively large slot corner radii, variable self-ligating bracket rigidity, and use of excessively small wires. [30] Torsional play obscures the differences between different prescription values. [31]

Several cross-sectional studies have shown that bracket positioning can have a significant impact on smile aesthetics as perceived by different groups of people. [32-35] Laypeople, for instance, tend to have a strong preference for a straight and harmonious smile. Orthodontists, on the other hand, consider several other factors such as facial balance, occlusion, and soft tissue profile, in addition to smile aesthetics. [32] Adolescent patients are particularly sensitive to the aesthetic outcomes of orthodontic treatment, and their satisfaction with the treatment outcome may be influenced by the appearance of the brackets. [32-33] In a study involving dental graduates from different disciplines, orthodontists were found to be more critical of the aesthetic outcomes of different bracket positions compared to other dental specialists. [32,34] Overall, these studies suggest that the perception

of smile aesthetics may vary widely among different groups of people, and bracket positioning can play an important role in achieving the desired aesthetic outcomes of orthodontic treatment.

Several limitations of this study should be considered when interpreting the results. Firstly, the number of studies included in this meta-analysis was relatively small, which may have limited the generalizability of the findings. Additionally, the heterogeneity between the studies was moderate to low, indicating that there may have been differences in the populations, interventions, and outcome measures that were not fully accounted for in the analysis. Furthermore, the quality of the included studies varied, which may have influenced the overall effect estimates. Specifically, the lack of blinding and randomization in some of the studies may have introduced bias into the results. Finally, it is important to note that this meta-analysis focused specifically on the impact of bracket positioning on SAP and did not consider other factors that may also be important in determining treatment outcomes, such as patient compliance and orthodontic technique.

CONCLUSION

The results obtained in this study show a statistically significant impact of bracket positioning on SAP, with improper positioning associated with decreased odds of protection. The findings of this study provide evidence for orthodontic practitioners to consider the impact of bracket positioning when aiming for optimal SAP. However, the limitations of this study should also be taken into account, including the small number of studies and the moderate to low heterogeneity between them. Future studies with larger sample sizes and improved methodological quality are needed to confirm and expand upon these findings. Overall, this study contributes to a better understanding of the relationship between bracket positioning and SAP, and highlights the importance of proper bracket positioning in achieving optimal orthodontic outcomes.

Declarations:

-Ethics approval and consent to participate: Not applicable

-Consent for publication: Not applicable

-Availability of data and materials: All data are available within the manuscript.

-Competing interests: The authors declare no conflict of interest with respect to this systematic review and meta-analysis.

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-Authors' contributions: Conceptualization, MKA, HA, MJA, RO; methodology, MKA, HA, MJA, RO; software, MKA, HA, MJA, RO; validation, MKA, HA, MJA, RO; formal analysis, MKA, HA, MJA, RO; investigation, MKA, HA, MJA, RO.; resources, MKA, HA, MJA, RO; data curation, MKA, HA, MJA, RO; writing—original draft preparation, MKA, HA, MJA, RO; writing—review and editing, MKA, HA, MJA, RO; visualization, MKA, HA, MJA, RO; project administration, MKA, HA, MJA, RO; All authors have read and agreed to the published version of the manuscript.

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