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Review

Guided Insertion of Temporary Anchorage Device in Form of Orthodontic Titanium Miniscrews with Customized 3D Templates—A Systematic Review with Meta-Analysis of Clinical Studies

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Abstract: (1) Background: Miniscrew insertion, using a surgical guide, aims to avoid possible adverse effects or complications. With the higher availability of both 3D imaging and printing, 3D surgical guides have been used more frequently in orthodontics. The aim of the present systematic review was to find scientific clinical evidence concerning the precision of the 3D guided insertion of miniscrews for temporary orthodontic anchorage. (2) Methods: Literature searches were performed in the following five search engines: Pubmed (Medline), Pubmed Central, Scopus, Web of Science and Embase on 10 September 2021 (articles from 1950 to 10 September 2021). A meta-analysis was performed using the random-effect model, with Standardized Mean Differences (SMD) and 95% confidence intervals (95% CI) calculated as effect estimates. The heterogeneity was assessed quantitatively. (3) Results: The search strategy identified 671 potential articles. After the removal of duplicates, 530 articles were analyzed. Subsequently, 487 papers were excluded, because they were not associated with the subject of the study. Of the remaining 43 papers, 34 were excluded because they did not meet the methodological criteria. Finally, only nine papers were subjected to a qualitative analysis. (4) Conclusions: The current literature concerning guided miniscrew insertion reveals, for the most part, a low methodological level. High-quality clinical trials are in the minority. The use of surgical guides increases insertion accuracy, stability and reduces the failure rate of orthodontic miniscrews. Tooth-borne insertion guides supported on the edges of the teeth ensure a higher insertion precision compared to mucosa-borne ones. The study protocol was registered in PROSPERO under the number CRD42021267248.

Keywords: guided insertion; surgical guide; orthodontics; mini-implant; temporary anchorage device; TAD; accuracy; precision

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1. Introduction

Orthodontic mini-implants (MIs), also called temporary anchorage devices (TADs), have been considered to be effective tools for intraoral anchorage reinforcement for many years [1]. Their main advantages are their easy application, the possibility to use them at various stages of treatment and the predictability of biomechanical effects [2]. The first scientifically documented attempts to use orthodontic mini-implants date back to 1945 [3]. Even then, attention was paid to the fact that insertion procedures may cause complications. Studies on adverse effects or complications concurrent to the application of miniscrews are scarce and present a low methodological quality [3]. However, it has been proved that complications due to the incorrect introduction of MI may lead to root injury and

periradicular lesion, of the buccal mucosa, or insertion into maxillary sinus or nasal floor (causing loss of vitality, pink discoloration or transitory loss of pulp sensitivity) [4–6].

Optimal positioning of the screw, taking into account root proximity [7], bone support as well as soft tissue thickness and quality, intends to avoid most complications [8]. For this purpose, surgical templates were introduced. In the glossary of prosthodontic terms, a surgical template is defined as a guide used to assist in the proper surgical placement and angulation of dental implants [9]. The main purpose of the surgical template is to direct drilling and ensure accurate implant placement according to the treatment plan. In order to accurately transfer the implant directly the surgical site, custom surgical templates based on radiological diagnostics have become the treatment of choice [10]. Miniscrew insertion using a surgical guide aims to avoid possible adverse effects or complications. A significant reduction of the failure rate was noticed when using detailed radiological diagnostics of the insertion site, nevertheless a two-dimensional X-ray is considered as sufficient for routine procedures [11]. However, some authors are of the opinion that it is necessary to perform CBCT on or before placing TADs in patients with severe space deficiency, significant tooth crowding, or extraordinary root position on panoramic radiographs [12]. At the turn of the century, wire guides, based on a periapical X-ray gained popularity [13], and they have been used successfully until now by many clinicians, especially if advanced diagnostic tools are unavailable [14]. With the higher availability of both 3D imaging and printing, 3D surgical guides, for which the effectiveness has been well documented in implantology, they have been used more frequently [15,16]. For many clinicians, they seem to present a new avenue, and are even seen as a new remedy for possible complications that may occur during MI insertion. However, they do not take into account key factors such as lack of operator experience, manufacturing costs of template fabrication, the influences of which have already been examined in the case of prosthetic dental implants [17,18]. Therefore, it seems justified to examine the validity of surgical-templates use, which may contribute a discussion on other aspects of guided insertion of temporary anchorage in orthodontics.

Numerous technical papers and case reports describing different systems for guided insertion of orthodontic miniscrews have been published in the last two decades [19–24]. Their authors try to ascertain both the accuracy and clinical effectiveness of various solutions, including 3D solutions. The aim of the present systematic review was to find scientific clinical evidence concerning the precision of 3D guided insertion of minis-crews for temporary orthodontic anchorage.

2. Materials and Methods

2.1. Search Strategy

This systematic review was conducted in accordance with the PRISMA statement (as shown in the Supplementary Materials) [25], the PRISMA reporting guidelines [26,27] and the Cochrane Handbook for Systematic Reviews of Interventions [28]. Literature searches were performed in across the following five search engines: Pubmed (Medline), Pubmed Central, Scopus, Web of Science and Embase on 10 September 2021. All searches were performed using a combination of subject headings and free-text terms, and the final search strategy was determined through several pre-searches. The keywords used in the search strategy were as follows: (“guided insertion” OR “guided surgical procedure” OR “surgical guide” OR “guided placement” OR “guided positioning”) AND (“mini-implant” OR “miniscrew” OR “TAD” OR “temporary anchorage device”) AND “orthodontics”. The study protocol was registered in PROSPERO database with the number CRD42021267248. The framework of this systematic review according to PICO [29] was as follows: Population: orthodontic patients; Intervention: 3D guided miniscrew insertion; Comparison: different protocols of guided orthodontic miniscrew insertion applied; Outcomes: accuracy, efficacy. The PICO question proposed was as follows: “In orthodontic patients does 3D guided miniscrew insertion, compared with different protocols (wire guide, manual insertion with digital planning), allow more accurate and effective miniscrew placement?”.

2.2. Eligibility Criteria

The following inclusion criteria were applied for this systematic review:

(1) Type of study: Quantitative randomized controlled clinical trials and quantitative nonrandomized clinical studies.
(2) Results of the study: Accuracy of 3D guided orthodontic miniscrew insertion in comparison to other methods.
(3) Objective of the study: Comparison of the efficacy and accuracy of guided orthodontic-miniscrew insertion procedure to standard procedure.
(4) Subject of the study: human subjects.

The following exclusion criteria were applied: reviews, incomplete studies (e.g., lack of control group), case reports, lack of effective statistical analysis; papers not related to guided miniscrew insertion, descriptions of the technique, studies not written in English.

2.3. Data Extraction

Titles and abstracts were independently selected by two authors (M.J. and J.J.-O.), following the inclusion criteria. The full text of each identified article was then analyzed to verify suitability for inclusion. Whenever disagreements occurred, they were resolved by discussions with the third author (G.G.), and by creating a worksheet in order to compare decisions in accordance with the Cochrane Collaboration guidelines [28]. The Cohen's K coefficient for the agreement between the authors was almost perfect and was of the value of 0.98. Authorship, year of publication, type of each eligible study and its relevance regarding the guided insertion of mini-implants with 3D guiding templates were extracted by one author (M.J.) and examined by another author (M.M.).

2.4. Quality Assessment

According to the PRISMA statements, the evaluation of methodological quality provides an indication of the strength of evidence included in th study because methodological flaws can result in biases [25]. Due to the wide range of types of studies which were finally included in this systematic review we decided to use the Mixed Methods Appraisal Tool (MMAT) [30]. This tool consists of the following two parts: checklist (Part I) and explanation of the criteria (Part II). The possible responses for all questions were: 'Yes', 'No' or 'Can't Tell'. The response 'No' to two of the screening questions or 'Can't tell' to one or both the screening questions might indicate that the paper cannot be appraised using the MMAT. Positive responses indicate a high quality of evidence presented in the study, while "Can't tell" indicates a failure to report exact results that meet the assumptions of the question. A quality assessment was independently carried out by two authors (M.J. and M.M.). We planned to discuss possible differences in the evaluation of the quality of the studies through discussion, but the authors assessed the quality of the studies in identical ways.

2.5. Meta-Analysis

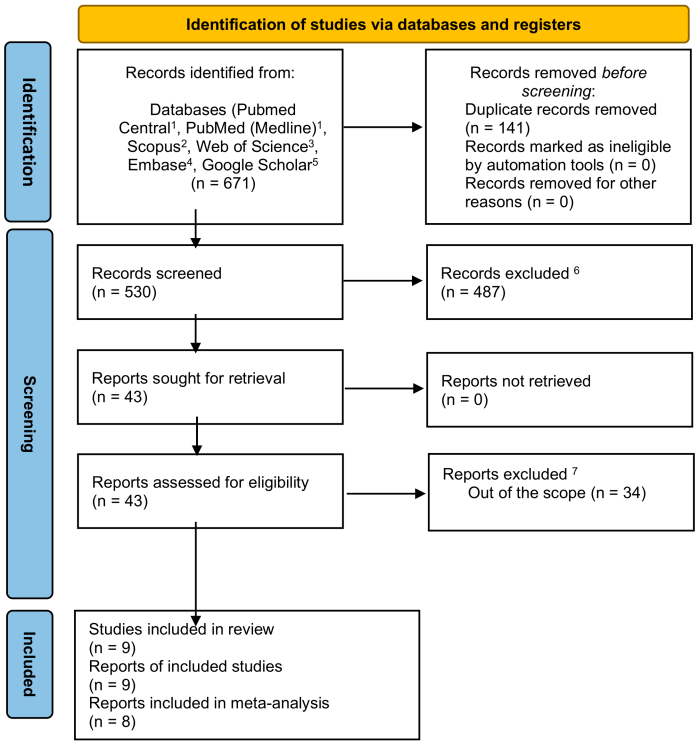
A meta-analysis was performed using the random-effect model via *metafor* and *compute.es R* packages [31], with Standardized Mean Differences (SMD) and 95% confidence intervals (95% CI) calculated as the effect estimates. Heterogeneity was assessed quantitatively using I^2-statistics and Cochrane's Q [32]. In cases where there were reported ranges instead of standard deviations, the range rule [33] was used to estimate standard deviations for use in this study. Publication biases were estimated using a funnel plot.

3. Results

3.1. Search Results

The search strategy identified 671 potential articles, including 72 from PubMed and PubMed Central, 155 from Scopus, 14 from Web of science, 2 from Embase and 428 from Google Scholar. After the removal of duplicates, 530 articles were analyzed. Subsequently, 487 papers were excluded because they did not meet the inclusion criteria. Of the remaining

43 papers, 34 were excluded because they were not relevant to the subject of the study (mainly about wire guided insertion or without proper statistical analysis). The excluded articles were mainly descriptions of techniques, case reports, case series or other papers that lacked an effective statistical analysis. Thus, only 9 papers were subjected to a qualitative analysis. A Prisma 2020 Flow Diagram representing the study selection process is presented in Figure 1. (Figure 1. Flow diagram) The main characteristics included of each study are presented in Table 1.



[1] - search string: ("guided insertion" OR "guided surgical procedure" OR "surgical guide" OR "guided placement" OR "guided positioning") AND ("mini-implant" OR "miniscrew" OR "TAD" OR "temporary anchorage device") AND "orthodontics"

[2] - search string: ALL (("guided insertion" OR "guided surgical procedure" OR "surgical guide" OR "guided placement" OR "guided positioning") AND ("mini-implant" OR "miniscrew" OR "TAD" OR "temporary anchorage device") AND "orthodontics") AND (LIMIT-TO (DOCTYPE , "ar"))

[3] - search string: ("guided insertion" OR "guided surgical procedure" OR "surgical guide" OR "guided placement" OR "guided positioning") AND ("mini-implant" OR "miniscrew" OR "TAD" OR "temporary anchorage device") AND "orthodontics" WEB OF SCIENCE CATEGORIES: (DENTISTRY ORAL SURGERY MEDICINE)

[4] - search string: ('guided insertion' OR 'guided surgical procedure' OR 'surgical guide' OR 'guided placement' OR 'guided positioning') AND ('mini-implant' OR 'miniscrew'/exp OR 'miniscrew' OR 'tad' OR 'temporary anchorage device'/exp OR 'temporary anchorage device') AND ('orthodontics'/exp OR 'orthodontics') AND [embase]/lim NOT ([embase]/lim AND [medline]/lim)

[5] – search string: ("guided insertion" OR "guided surgical procedure" OR "surgical guide" OR "guided placement" OR "guided positioning") AND ("mini-implant" OR "miniscrew" OR "TAD" OR "temporary anchorage device") AND "orthodontics"

[6] – incomplete studies, reviews, in-vitro studies, papers not related to guided TAD insertion, studies not written in English.

[7]- because of the lack of effective statistical analysis, description of the technique, case reports

Figure 1. Search strategy—Prisma 2020 flow diagram.

Table 1. Characteristics of included studies.

Author and Year	Type of Article	Material or Subjects	Control Sample or Group	Method	Outcome Measured	Results
Suzuki and Suzuki, 2007 [34]	Case—control study	180 implants inserted with the use of a 3D surgical guide	(a) 20 implants inserted using a conventional wire guide (b) 20 implants inserted without any guide	Measurements on periapical radiographs	Deviation from "gold standard" lines projected by specialized software	The mean coronal deviation was 0.4–0.6 mm for the 3D surgical guide method, 0.4–1.0 mm for the wire guide, and 1.4–3.6 mm for the no-guide method. The mean apical deviation was 0.4–2.0 mm for the 3D surgical guide, 1.1–5.3 mm for the wire guide, and 3.5–10.5 mm for the no-guide method. All the mini-implants were inserted into interradicular space.
Rashid et al., 2021 [35]	Randomized split-mouth clinical trial	25 implants inserted with the use of a 3D surgical guide	25 implants inserted without any guide	Measurements on CBCT scans	Deviation from "gold standard" lines projected by specialized software	The mean values for apical deviation were 0.69 ± 0.02 mm for guided screws and 1.44 ± 0.10 for hand-drilled screws, and 0.60 ± 0.03 and 2.47 ± 0.27 for coronal deviation, respectively. The mean mesiodistal angle was 2.53 ± 0.10 for guided implants and 11.67 ± 0.75 for hand-drilled group. The mean bucco-lingual angle was 0.18 ± 0.09 and 10.25 ± 0.91, respectively. All the mini-implants were inserted into interradicular space.
Dasomi Kim, 2019 [36]	Randomized clinical trial	45 implants inserted with the use of a 3D surgical guide	47 implants inserted manually without any guide	Measurements on periapical radiographs, CBCT, insertion torque and Periotest	Percentage of success rate, root contact, insertion torque and Periotest	In the manual insertion group the success rate was 80.9% and for the guide group it was 88.9%. The root contact rate was 31.9% in the manual group and 0.4% in the surgical guide group. The insertion torque was 6.37 ± 2.64 Ncm in the manual group and 6.54 ± 2.90 Ncm in the guide group, and the Periotest value was 0.19 ± 2.86 in the guide group and 1.58 ± 2.13 in the manual group. All the miniimplants were inserted into interradicular space.
Mi-Ju Bae, 2013 [37]	Nonradmized clinical experimental study	25 implants inserted with the use of a 3D surgical guide	20 implants inserted using a wire guide and periapical radiographs	Measurements on CBCT scans	Deviation from "gold standard" lines projected by specialized software	Median long-axis angular deviations were 3.14° (range, 1.02°–10.9°) for the surgical guide group and 9.57° (range, 3.15°–35.60°) for the control group. The mean apical deviation 0.73 was for the surgical group and 1.28 for control group. The mean coronal deviation was 0.73 for the surgical group and 1.56 for the control group. All the mini-implants were inserted into interradicular space.