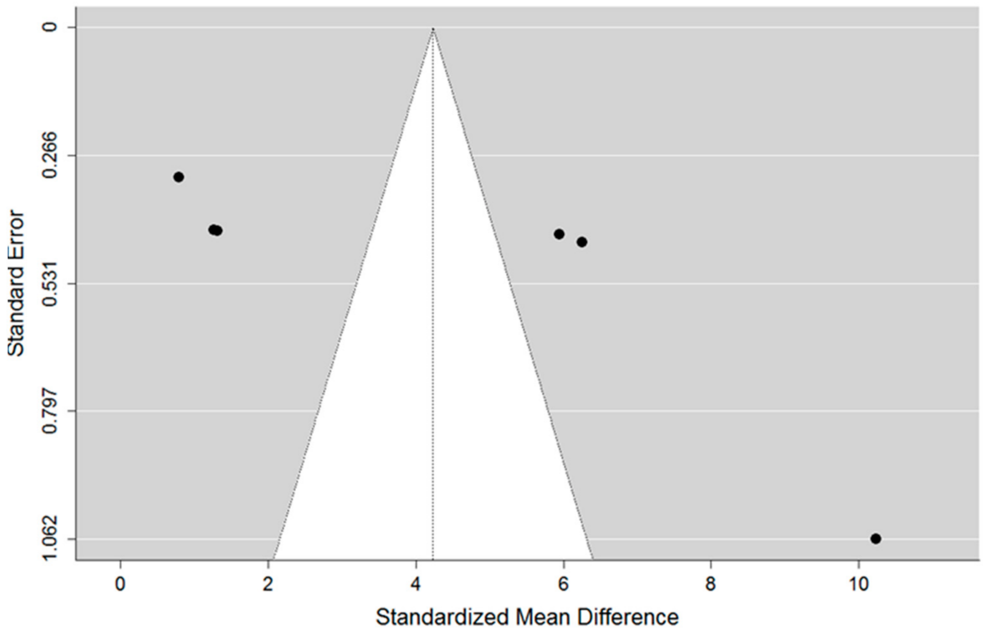

Figure 5. Funnel plot of 4 studies suggests publication bias.

(c) The third comparison

There were 3 included studies in the meta-analysis. The results are shown on Figure 6. Positive value of Standardized mean difference indicates a greater efficacy of a tooth-borne surgical guide, negative—of a gingiva-borne surgical guide.

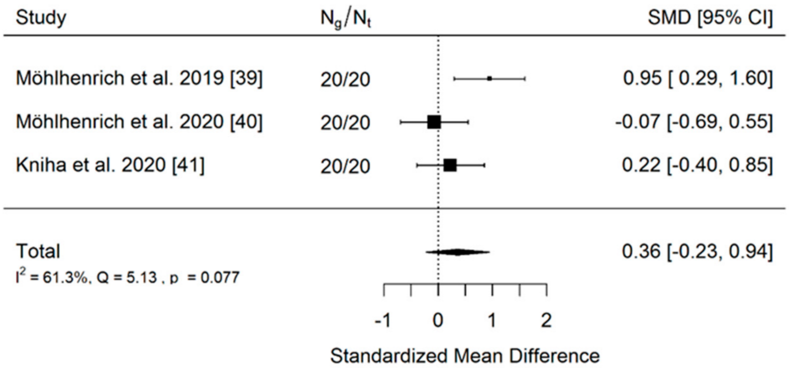

Figure 6. Forest plot of 3 studies of the third comparison performed. N_g—number of mini-implants inserted with gingiva-borne (mucosa-borne) surgical guide; N_t—number of mini-implants inserted with tooth-borne surgical guide.

Positive value of SMD indicates a greater efficacy of the tooth-borne surgical guide, negative—of a gingiva-borne surgical guide. Ng and Nt—number of gingiva-borne and tooth-borne surgical guides. The usage of tooth-borne surgical guide vs. gingiva-borne surgical guide has an insignificant (p = 0.231) positive effect size. Study results are consistent—heterogeneity is insignificant (p = 0.077), around 61% of the variability derives from heterogeneity. The funnel plot (Figure 7) does not reveal a publication bias.

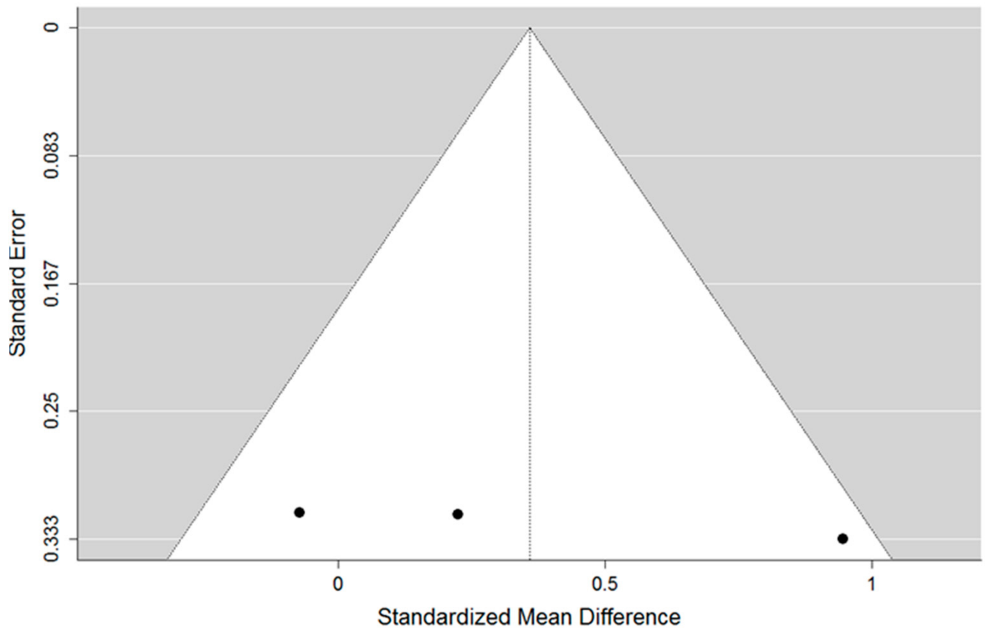

Figure 7. Funnel plot of the third comparison did not reveal any publication bias.

4. Discussion

This systematic review aimed to find scientific evidence justifying the use of 3D surgical guides for mini-implant insertion in everyday orthodontic practice. The number of articles included may appear small given the overall literature on guided mini-implant insertion [34–42]. However, most papers are based on a very limited numbers of cases and lack appropriate control groups to adequately assess the potential benefits of using 3D surgical guides [18–24,43–46]. It should be taken into account that guide fabrication makes guided mini-implant procedures more expensive and more time-consuming than direct manual insertion. However, as of yet no studies have been published regarding the cost-effectiveness of the 3D guided procedure. The authors intended to find evidence both on precision and efficacy. Finally, clinical efficacy, described in the form of an assessment of the comfort of solutions based on micro-implants, was only described in one paper.

Among the different scales for the quality assessment of scientific papers, the authors selected the MMAT, intending to unify a quality assessment of all the studies included in this systematic review and to avoid the over-division of a quality assessment by using type-specific scales.

The overall quality of the studies according to the scale applied seem to be a consequence of the strict inclusion criteria applied in the present study. One of the criteria of quality assessment refers to the participants' adherence to the assigned intervention. Since the intervention in the studies included [34–42] the insertion of a screw, the studies included gained favorable scoring with regard to the criterium mentioned. Similarly, the score is found to be positive in terms of administering the intervention or the occurrence of exposure during the study period, as intended.

The apical deviation in mm was selected as a variable for a meta-analysis because of its high clinical relevance (comparing to angular or coronal deviation) [47]. The clinician primarily wants to avoid root contact or damage to important anatomical structures that are situated at a deeper level [47,48]. The publication bias and the heterogeneity may be explained by the constant technological progress in dentistry. The oldest study included in the review is from 2007 and the newest is from 2021. It is obvious that the CAD/CAM technique has become much more advanced (±2 mm of accuracy in the study coming from 2007 to ±0.69 mm from the study coming form 2021). The variables obtained in the most recent studies are definitely found to be smaller than those considered small using the IT equipment from past studies. Hence, the differences in the reported values observed on the funnel plot, despite clear and uniform tendencies, are noticeable on forest-diagrams. On the other hand, the third funnel plot did not reveal a publication bias (Figure 7) probably due to the fact that the research included originates from a much shorter period of time. Therefore, it should be assumed that the technological solutions used in the studies are comparable. It is also important to consider that the data included in the first two comparisons concern interradicular spaces, while the third concerns mini-implants inserted into the palate. Furthermore, one should not forget about the heterogeneity resulting from the different methods of performing the procedure (operator-bias), implant system, drilling method and analysis as to the certainty of introduction. In some cases they were objective methods (Periotest), in others a subjective analysis of the operator was followed by radiological analysis. Nevertheless, in view of the meta-analysis performed, the results of research on mini-implants inserted into the palate can be considered more reliable than the ones on mini-implants inserted into interradicular spaces. However, regardless of the year and insertion site of the studies included, using a 3D surgical guide has always had a significant positive impact on accuracy compared to other methods.

In the study by Bae et al. the 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 was 0.73 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. The fact that the authors of the study cited present a median of the angular measurements indicates a high diversity of the measurements, which may indicate a low predictability of the direction of the screw insertion, especially using a wire guide. Furthermore, other articles included in the review show that angular deviation proves to be the value with the greatest variability between studies. This confirms the necessity to ensure a control group while performing this type of research, due to the high dependence of the results on the specific operator.

Numerous studies that use CBCT to assess bone amount and quality as well as root proximity in terms of placing orthodontic mini-implants for temporary anchorage [36,48,49] have been published in recent years. An assessment of the conditions at the planned surgical site is crucial. Factors considered crucial to the successful insertion of the implant include mini-implant length and diameter, the site of insertion and the patient's age [50]. An interesting practical novelty is the scientific evidence provided by Möhlhenrich et al. that an intraoral scan, taken in order to superimpose on a previously performed CBCT, is sufficient for the accurate analysis of mini-implant position [40,41]. Thus, the patient is protected from additional X-ray radiation exposure and the intraoral scanner gains a new clinical application, leading to the more frequent use of scanners in everyday orthodontic practice [51].

Many recent studies investigate implant stability [52–54] since mini-implant loss requires new screw insertion and is associated with patient's dissatisfaction. Interestingly, mini-implants introduced through guides, primarily 3D guides, are characterized by superior biomechanical features over those introduced manually. This fact should be considered as another significant advantage in favor of guided insertion. It seems that 3D surgical guides are especially beneficial for patients with narrow interradicular spaces. Kuroda et al. stated that root proximity presents the major risk of failure while using mini-implants, due to worse biomechanical characteristic of such anchorage [55]. On the other hand, mini-implants inserted with 3D surgical guides are also characterized by higher values of removal torque. This is not surprising, given the fact that a higher removal torque is associated with better osseointegration [56]. This is consistent with the Perio test values presented in the study by Dasomi et al. [41]. It should be into consideration that not only the insertion, but also the removal of miniscrews have been associated with adverse effects such as secondary bleeding, miniscrew fracture, scars, and exostosis [4]. Future research could be directed towards the use of artificial intelligence, as it is successfully used in many branches of dentistry, for detailed surface analysis, tissue composition and CBCT images [57,58]. Possible limitations of the present study may derive from the fact that the studies included used different software, various materials for printing guides and different types of mini-implants. Moreover, they were performed across a period of more than 14-years, which could significantly influence the accuracy of MI systems and imaging software. Another limitation is the scarce amount of data contained in each of the meta-analyses performed, which results from the limited availability of relevant studies. In the future, it would be worth carrying out a cost-effectiveness study to determine whether economic benefits exist in fabricating 3D templates for orthodontic MI placement.

5. Conclusions

(1) The current literature concerning guided MI insertion consists primarily of articles presenting a low methodological level, mainly technical papers or studies carried out without a control group. High-quality clinical trials, which exclude software-bias and operator-bias in their methodological flow, are in a minority.
(2) The use of surgical guides increases mini-implant insertion accuracy and stability and reduces the failure rate of orthodontic miniscrews.
(3) Tooth-borne insertion guides, supported on the edges of teeth, ensure a higher insertion precision compared to mucosa-borne guides.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/coatings11121488/s1, Table S1: Prisma 2020 Checklist, Table S2: Prisma 2020 For Abstracts Checklist.

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Abbreviations

TAD	Temporary anchorage device
MI	Mini-implant
CBCT	Cone Beam Computed Tomography
MMAT	Mixed Methods Appraisal Tool

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