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Clinical Experience and Digital Knowledge in Virtual Planning of Palatal Orthodontic Miniscrew Insertion

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Abstract: At present, temporary anchorage devices (TADs) are continuously gaining importance because of their usability and their possibility to broaden clinical force applications; however, how difficult can their placement planning be? Aim: The aim is to evaluate the association between clinical experience, digital knowledge and the capability of virtual planning in palatal orthodontic miniscrew insertion in various types of clinicians, divided by different levels of experience. Methods: A total of 30 participants (10 dental students, 10 orthodontics students and 10 orthodontists) with different levels of clinical and digital experience were randomly recruited in this cross-sectional study. All participants performed a pre-test survey followed by two consecutive digital planning tests and, finally a post-test survey. The digital planning test was made using software BlueSkyBio-BlueSkyPlan, a surgical guide module. The differences in terms of planning execution time, miniscrew insertion and surgical guide realization were evaluated. The Kruskal–Wallis and Mann–Whitney U-tests were performed to determine the effects of independent variables and interactions between groups. Results: The relation between clinical experience and bicorticalism was statistically significant ($p = 0.017$); in the planning execution time, a significant difference was evident between the dental students and the orthodontics students (T1: $p = 0.015$ and T2: $p = 0.019$), who, having good digital knowledge, took an average of 4.58 min less in T1 ($p = 0.025$), while this difference was significantly reduced in T2 ($p = 0.106$). Conclusion: Clinical experience increased miniscrew placement accuracy and digital knowledge reduced execution planning time but both had a stronger impact in the first test than in the second.

Keywords: orthodontics; software; bone screw; maxilla; palate

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1. Introduction

Orthodontic miniscrew implants (MSI), a type of temporary anchorage device (TAD), are skeletal anchorage units that do not deliver any kind of force on teeth when an orthodontic movement is required [1]. At present, TADs are continuously gaining importance because of their usability and their possibility to broaden clinical force applications. MSI provide acceptable success rates that vary among the explored insertion sites [2]. Potential sites for MSI placement in the maxilla include the area below the anterior nasal spine, the palate (either on the midpalate or the paramedian palate), the infrazygomatic crest, the maxillary tuberosities and the alveolar process (both buccally and palatally between the roots of the teeth) [3].

Among the various sites proposed for the insertion of MSI, the anterior portion of the palate has been gaining increasing interest in recent years, presenting significant advantages such as relative safety in the paramedian area, given the absence of significant vessels or nerves (with the exception of the nose-palatine canal), absence of dental roots, and presence of sufficient bone and cortex, with only adherent gingiva. As a consequence of these characteristics, the insertion of MSI in the anterior area of the palate shows a definitively lower failure rate than the inter-root insertion, as confirmed by several studies [4–7].

Skeletal anchorage in the anterior palate is optimal for supporting various treatment mechanics, including distalization [8], rapid maxillary expansion [9], space closure [10], intrusion mechanics [11], canine disimpaction [12–14] and final incisor position relative to the facial profile esthetics [15,16]. Furthermore, orthodontists can address more complex clinical situations, such as severe open bite [17], impacted teeth [18] or mixed dentition [19].

TADs' placement can be accomplished with or without previous digital planning. Both direct and three-dimensional (3D)-assisted TAD insertion methods are safe and accurate in the anterior palate [4].

The need to increase the predictability in miniscrew insertion brought about the development of techniques that allow the clinician to deepen their case study in order to achieve better results. The introduction of computer-aided design and computer-aided manufacturing (CAD-CAM) software made digital planning available, allowing clinicians to design miniscrew insertion and potential customized devices to handle different issues [20,21].

The precision acquired with digital planning has to be then transferred to the oral cavity itself and this can be achieved with a custom-made 3D-printed surgical guide [22]; the use of insertion guides may facilitate TAD insertion, providing the opportunity to use palatal MSI for less-experienced clinicians [4,22–25].

The digital planning of an MSI insertion has to be accomplished by the clinician themself and may be thus considered operator-dependent. The aim of this study is to evaluate the association between clinical experience and digital knowledge, and the capabilities of virtual planning in palatal orthodontic miniscrew insertion.

2. Materials and Methods

A total of 30 clinicians, with different levels of clinical and digital experience, were randomly recruited in this cross-sectional study to evaluate the capacity of virtual planning in palatal orthodontic miniscrew insertion. The investigation was reviewed and approved by the regional Ethical Review Board of the Umberto I Polyclinic Hospital, Rome Italy (N.4663) The sample was recruited from January to September 2022 and was composed of three groups: 10 dental students (all attending their sixth year of the dentistry course at Sapienza University of Rome), 10 orthodontics students (orthodontics postgraduate school of Sapienza University of Rome) and 10 orthodontists (orthodontic specialists in Rome). To determine appropriate sample size, pilot experiments were conducted, and this was calculated as 10 per group, in order to have an 80% probability of detecting 20% knowledge difference among groups with a 95% ($p < 0.05$) level of significance.

All participants performed a pre-test survey followed by two consecutive digital planning tests and, finally, a post-test survey. All participants signed an informed consent form for participation in the study, both in the surveys and in the tests; an identification code was used for each participant for privacy reasons. The pre-test and the post-test surveys were made by Google Forms® program, creating two surveys with multiple choice questions. (Data available in the Appendices A and B).

The pre-test survey was performed by all clinicians to evaluate clinical experience and digital knowledge. This survey was composed of 2 sections (7 questions in total) of which the first section was regarding clinical experience on miniscrew placement and the second section was about digital knowledge in the use of Digital Imaging and Communication in Medicine (DICOM) image evaluation software and, in particular, digital planning of TADs insertion. The evaluation of the clinical experience was based on a self-assessment test of the theoretical and practical knowledge and the clinical experience of the participants in the positioning of palatal miniscrews by means of 4 questions (Appendix A 1–4). A score was assigned to each question and a final scale from 0 to 3 was obtained, indicating the level of clinical knowledge of the participant. Later, the answer was transformed into "YES clinical experience" (a score of 2 or 3) or "NO clinical experience" (values less than 2) based on the test result. In the same way, previous digital knowledge in the treatment of medical images was evaluated through a self-assessment test (Appendix A 5–7) assigning a value to each question from 0 to 3 and obtaining a final evaluation as "YES digital knowledge" (a score of 2 or 3) and "NO digital knowledge" (values less than 2).

The digital planning test was made using software BlueSkyBio-BlueSkyPlan© ver. 4.7.55, surgical guide module. All tests were performed on the same patient's examinations, ensuring comparison criteria between the tests. For all the participants, it was their first time using this software. The patient was selected from the Department's Orthodontic Unit list among those who would have performed miniscrew-assisted distalization. The patient records used were a facial skeletal CBCT (prescribed because this specific patient had to undergo presurgical orthodontic treatment) made with Carestream CS 8200 3D machine (volume of 150 × 100 × 80 mm), and an oral scan obtained by scanning a cast made from an alginate impression using Carestream CS 3500 oral scanner. Before the performance, all the clinicians were instructed to view an introductory video guide supplied by the software's team. A folder containing a CBCT and a Standard Triangle Language (STL) impression file of the patient was given to each clinician, with the instructions to match the two files and place two miniscrews in the anterior part of the palate and then generate a surgical guide to reproduce the planned insertion in the patient's oral cavity. The phases described are represented in Figure 1. The test was conducted two consecutive times, with the purpose of evaluating the differences in terms of planning execution time, miniscrew insertion and surgical guide realization.

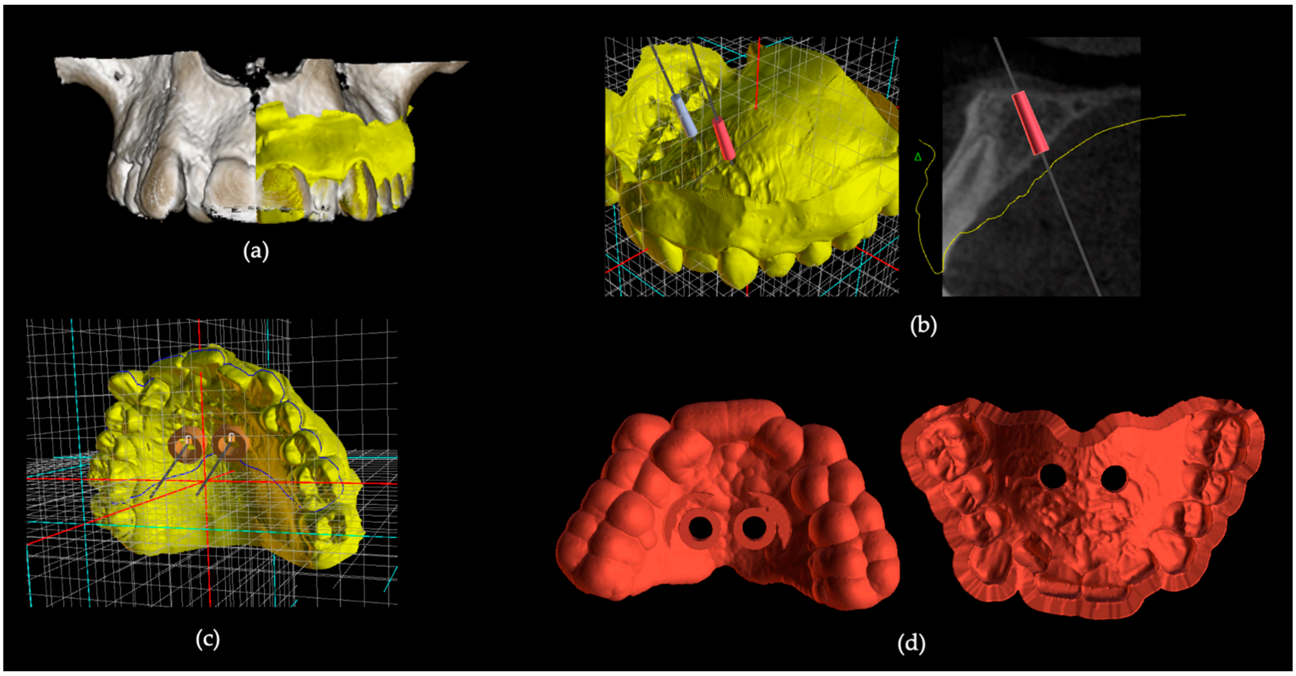

Figure 1. (**a**) On the left, segmented maxillae from the CBCT and, on the right, matching of CBCT and STL file; (**b**) implant insertion in 3D view and cross-sectional view; (**c**) perimeter of the surgical guide and implants rings; and (**d**) surgical guide exported and ready to be 3D-printed.

In the digital planning tests, 3 groups of variables were evaluated: miniscrew insertion, the surgical guide design and planning execution time.

1. The miniscrew insertion was evaluated through four variables: safe-zone miniscrew placement, bicorticalism achieved, proximity to the incisive foramen and proximity to the incisive root.
   1.1 *Safe-zone miniscrew placement* was evaluated as positive if both the screws were placed in the 3rd rugae area [13].
   1.2 *Bicorticalism* achieved was evaluated as positive if both the screws reached the opposing cortex of the palate [26,27].

1.3 *Proximity to the incisive foramen* was evaluated as positive if at least one of the two miniscrews was placed in contact with the incisive foramen [28].
1.4 *Proximity to the incisive root* was assessed as positive if at least one of the miniscrews was placed in contact with the incisive root [28].

2. Surgical guide design was evaluated thorough three variables: posterior extension, vertical extension and position of the two rings (the empty circular hole that drove the insertion process itself).
   2.1 *Posterior extension* was considered correct when the surgical guides extended up to the first permanent molar and not distally [29].
   2.2 *Vertical extension* was considered correct if the surgical guide was extended halfway up the crown to achieve retention, by taking advantage of some undercut, and stability of the guide, by wrapping the occlusal face of the teeth [29,30].
   2.3 *The positioning of the rings* was evaluated through two variables: the overlapping of the rings between them, considering the positioning of the rings separately as correct and the overlapping of the rings with the image corresponding to the palatal mucosa, considering the position of the ring as correct if there was no merging of the rings with the mucosa.
3. Planning execution time was considered as the time in minutes from the opening of the software to the completion of the virtual design of the surgical guide.

The *post-test survey* was performed to evaluate post-operative knowledge and potential difficulties detected during the tests. The survey was composed of 2 sections (5 questions in total) of which the first section concerned a self-evaluation of post-operative knowledge and, the second, the difficulties encountered.

All the data from the study were analyzed using IBM SPSS Statistics 25 (IBM, Chicago, IL, USA). Qualitative variables were written as counts or percentages and were tested using Fisher's Exact tests. Quantitative variables were tested for normal distribution using the Shapiro–Wilk Test and were written as averages with standard deviations. The Kruskal–Wallis and Mann–Whitney U-tests were performed to determine the effects of independent variables and interactions between groups. A *p*-value of <0.05 was considered statistically significant.

3. Results

Thirty participants were recruited (10 dental students, 10 orthodontic postgraduate students and 10 orthodontists) to participate in the study by answering the surveys and performing the test with the software twice.

A total of 73.3% of the clinicians were female, with a similar distribution among the study groups (dental students, 80%, orthodontics students, 80% and orthodontists, 60%).

All dental students were under 30 years of age, all the orthodontics students were between 26 and 40 years of age and 90% of the orthodontists were over 40 years of age. The distribution by age group showed a statistically significant difference between the study groups ($p = 0.001$).

3.1. Clinical Experience and Digital Knowledge between Groups (Pre-Test Survey)

In the evaluation of the distribution of clinical experience among the participants, no statistically significant difference was observed between the groups ($p = 0.535$); however, the clinical experience increased from dental students to orthodontists. (Table 1).

The Orthodontics Student group showed a higher percentage of participants with digital knowledge in relation to the other two groups. However, the difference was not statistically significant ($p = 0.076$). (Table 2).

Table 1. Clinical experience by Study Group.

			Study Group			Total	
			Dental Student	**Orthodontics Student**	**Orthodontist**		***p*-Value**
Clinical experience	No	Count	3	2	1	6	0.535
		% within Study Group	30.0%	20.0%	10.0%	20.0%	
	Yes	Count	7	8	9	24	
		% within Study Group	70.0%	80.0%	90.0%	80.0%	
Total		Count	10	10	10	30	
		% within Study Group	100.0%	100.0%	100.0%	100.0%	

Fisher's Exact tests. *p*-value < 0.05 was considered statistically significant.

Table 2. Digital knowledge by study group.

			Study Group				
			Dental Student	**Orthodontics Student**	**Orthodontist**	**Total**	***p*-Value**
Digital Knowledge	No	Count	7	2	4	13	0.076
		% within Study Group	70.0%	20.0%	40.0%	43.3%	
	Yes	Count	3	8	6	17	
		% within Study Group	30.0%	80.0%	60.0%	56.7%	
Total		Count	10	10	10	30	
		% within Study Group	100.0%	100.0%	100.0%	100.0%	

Fisher's Exact tests. *p*-value < 0.05 was considered statistically significant.

3.2. Miniscrew Insertion

3.2.1. Safe-Zone Evaluated According to Group, Clinical Experience and Digital Knowledge

- In T1, 70% of the orthodontists inserted miniscrews in the safe-zone, at the level of the third palatal rugae. In the groups of orthodontic students and dental students this was 60% and 50%, respectively; however this difference was not statistically relevant ($p = 0.387$).
- Regarding the insertion in the safe zone, considering the clinical experience of the participants, despite the fact that there was no statistically significant difference ($p = 0.197$), it was observed that 88.2% of the participants who correctly positioned the miniscrews in the safe zone in T1 had clinical experience.
- Digital knowledge did not show any relationship with the correct positioning of the implants in the safe zone for any of the study groups.
- The participants did not show variation in the positioning of the miniscrews in T2 compared to T1 in any of the study groups ($p = 0.259$).

3.2.2. Bicorticalism Evaluated According to Group, Clinical Experience and Digital Knowledge

- Regarding the achievement of bicorticalism, 40% of the dental students, 50% of the orthodontics students and 60% of the orthodontists obtained it for both miniscrews in T1, but this difference was not revealed to be statistically significant ($p = 0.670$). Obtaining bicorticalism during miniscrew positioning did not show a significant variation in T2 ($p = 0.133$).
- Analyzing the difference considering the clinical experience of the operators, it was observed that 100% of those who achieved bicorticalism had clinical experience ($p = 0.017$).
- No relationship was observed between obtaining bicorticalism and digital knowledge for any of the study groups at T1 and T2 (T1: $p = 0.671$; T2: $p = 0.713$).

3.2.3. Proximity to the Incisive Foramen and to the Incisive Root

- Only one operator positioned one of the miniscrews in proximity to the incisive foramen in T1 but not in T2.

3.3. Surgical Guide Design

- Regarding the design of the surgical guide, no significant differences were observed in any of the variables considered (posterior extension, vertical extension and position of the two rings) between the study groups.
- No significant variations were observed in the surgical guide parameters between T1 and T2 in all samples. Clinical experience and digital knowledge did not influence the correct design of the surgical guide.

3.4. Planning Execution Time

Table 3 shows the mean values of time spent in digital planning in T1 and T2 according to study group. A significant difference between the groups was observed in T1 and T2 (T1: $p = 0.012$) (T2: $p = 0.016$).

Table 3. Planning execution time (T1 and T2) by Study Groups.

Study Group		**Mean**	**N**	**Std. Deviation**	**T1–T2 *p*-Value**	**T1 *p*-Value**	**T2 *p*-Value**
Dental Student	T1 (Time in minutes)	23.7370	10	6.72756	0.001	0.012	0.016
	T2 (Time in minutes)	15.6800	10	4.25727			
Orthodontics Student	T1 (Time in minutes)	16.9220	10	3.77017	0.001		
	T2 (Time in minutes)	11.5720	10	2.32213			
Orthodontist	T1 (Time in minutes)	18.3750	10	3.85744	0.003		
	T2 (Time in minutes)	12.4460	10	2.33010			

Paired *t*-tests for T1–T2 and Kruskal–Wallis test for T1 and T2 evaluation. *p*-value < 0.05 was considered statistically significant.

- In the intergroup analysis, a significant difference was evident between the dental students and the orthodontics students (T1: $p = 0.015$ and T2: $p = 0.019$).
- The time was significantly reduced, with a mean of 6.44 min less, in T2 in all of the samples.
- In the evaluation of the relationship between the planning execution time and previous theoretical or clinical experience of the participants in T1 and T2, no significant differences were observed in the general sample or in the sample divided by study groups (T1: $p = 0.180$; T2: $p = 0.948$).
- Evaluating the relationship between planning execution time and digital knowledge of the participants in T1 and T2, it was observed that, in the general sample, those who had digital knowledge took an average of 4.58 min less in T1 ($p = 0.025$), while this difference was significantly reduced in T2 ($p = 0.106$). (Table 4).

Table 4. Planning execution time (T1 and T2) by previous Digital Knowledge.

Digital Knowledge		**N**	**Mean**	**Std. Deviation**	***p* Value**
T1 (Time in minutes)	No	13	22.2769	6.75231	0.025
	Yes	17	17.6906	3.74830	
T2 (Time in minutes)	No	13	14.5315	4.42594	0.106
	Yes	17	12.2394	2.24171	

Mann–Whitney U-test. *p*-value < 0.05 was considered statistically significant.

3.5. Self-Evaluation and Difficulties Detected (Post-Test Survey)

- The survey given to the participants after completing the two tests reflected that, in the orthodontist group, the greatest difficulty was the design of the surgical guide

(40%), while for the dental students and orthodontics students groups, the positioning of the miniscrew was more difficult (50% and 40%, respectively).

- An average of 80% of the clinicians considered their own individual software use capabilities to have improved after the second test; this result had no significance between the groups (p = 0.535).

4. Discussion

In this cross-sectional study, the association between clinical experience and digital knowledge and the capacity of virtual planning in palatal orthodontic miniscrew insertion was evaluated. The test was conducted by three groups of clinicians with different clinical and digital experience (dental students, orthodontics students and orthodontists).

The assessment of the individual skills regarding miniscrew virtual positioning according to the level of training seems to have not yet been studied in the literature. Similar studies were performed evaluating differences on digital planning between groups selected by different type of experience on clinical and digital topics [22,31–33]. Nevertheless, none of these regarded digitally planned miniscrews insertion. For this study, the use of CBCT was chosen in order to achieve a precise construction of the surgical guide and to evaluate the clinicians' skills, comparing the participants amongst each other. Digital planning is possible with just the radiographical exams and dental scans of the patient. On this topic, there is a debate between authors; some say cone beam computed tomography (CBCT), a volumetric 3D radiographic exam, is mandatory in achieving optimal results. On the contrary, some others say it is, in fact, not [20–23]. G. Maino et al. [34] and D. Wilmes et al. [21] describe how a dental scan can be simply superimposed on a lateral cephalogram, exploiting only a sagittal plan, because there is no need to verify bone density and thickness of the anterior palatal area. On the other hand, Nienkemper et al. [20] and Akdeniz B. et al. [35] claim that an accurate analysis of bone quantity and depth cannot be provided by the use of lateral cephalogram alone.

The clinician has to first import the DICOM and the STL files, then overlap the two and insert the two implants. The last step is to generate the digital surgical guide, including the implants and teeth for retention [22–24,28,30,36–39].

In this study the orthodontists' group demonstrated more clinical experience but this was not statistically significant, thus reflecting the interest of the students for this topic. However, the more extensive clinical experience of the orthodontists can be confirmed by the results obtained in the test, in particular in the sections "respect of the safe zone" and "bicorticalism achievement". In the post-test survey, the same group mostly reported "surgical guide realization" as the answer to the question "What was the most difficult part?", highlighting a greater lack of digital knowledge when compared to the other groups. This answer can be considered as the one most related to "digital knowledge". On the other hand, the orthodontics students demonstrated a higher digital knowledge, but this was not statistically significant either. Despite the lack of statistical significance, the previously mentioned assumption may be confirmed by the results obtained in "planning execution time", in which orthodontics students showed the best result. Instead, for the orthodontics students' group, a greater lack of clinical experience was highlighted by the answer to the post-test survey question "What was the most difficult part?" in which the most commonly selected answer was ''miniscrew insertion". This answer can be considered as the one most related to "clinical experience".

Son K. et al. selected a group of 14 dental technicians and 14 dental students, asking them to virtually design a custom implant abutment three times and evaluating the correlation between computer literacy and planning execution time. This resulted in a shorter time for the clinically experienced group (dental technicians), but the group with the higher reduction time between the tests was the preclinically experienced group (dental students), showing a statistically significant correlation between execution time and computer literacy [32]. The same team, in another study, chose to compare instead the performance of 12 dentists, 12 dental technicians and 12 dental students on the same type of test and evaluated the planning execution time in this case too. This resulted in a shorter time for dental technicians in the initial test, with a progressively less important difference in the following tests [33]. O'Connor Esteban M et al. [40] selected, instead, a group of dental surgeons with 5–10 years' experience and a group of dental surgery students and asked them to virtually plan the insertion of dental implants in a completely edentulous patient's maxilla in two stages, with and without a virtual mock-up obtained by an oral scan of the patient's mouth. The team evaluated the discrepancies between the two groups and the two tests, showing how digital planning, helped by a virtual mock-up, is more useful for students to reduce the risk of badly placed implants. Some of these studies also evaluated the tests made with two different forms of software to show potential discrepancies in the planning process [31–33]. Excluding O'Connor et al. [40], no other study evaluated the accuracy of the work.

An important result is that 88,2% of all clinicians that positioned the screw in the "safe zone" answered positively, in the pre-test survey, to the "clinical or theoretical experience" question. The totality of the sample that achieved "bicorticalism" in the test answered positively to the same question. On the same topic, almost all the sample placed the screw without hurting the incisive foramina and roots. From these results, it is clear that many clinicians in the sample have experience on the topic and, even if basic, this experience is reflected in the good results in the test.

All the clinicians who answered positively to the "digital knowledge" questions showed shorter performances than the others in the first test, even if, in another field of investigation, this result can be considered similar to that in Son K. et al.'s study [33]. This gap was then reduced in the second test, a value that is reflected in the continuous reduction in the influence of pre-existing digital knowledge [32]. In all the sample there was, instead, a significant reduction in time from the first to the second test, reflecting a great improvement. From these results, it seems that the use of the software's settings represents a mechanical task that may be accomplished at a progressively quicker speed each time; hence, this may contribute to a reduction in the total planning time required.

The evaluation of "Surgical Guide realization" did not show any significant difference between the two tests and was not affected by clinical experience and digital knowledge. A possible reason for this may be attributed to the pre-test explanation via the video guide lesson on the software's use, and to the basic instructions delivered by the members of the study redaction team.

The limitation of this study is the small number of participants belonging to each group and the small total sample.

A future prospective research avenue is to repeat the test more than just twice, to provide a larger sample and to carry out the clinical treatment by printing the guide and inserting the implants in the patient's mouth.

5. Conclusions

In this cross-sectional study of the virtual insertion planning of orthodontic miniscrews in the palate by different participants, it is stated that:

- Participants who had previous clinical experience obtained more accuracy in miniscrew positioning;
- Both clinical experience and digital knowledge were shown to be important for generating a virtually planned miniscrew insertion.
- Digital knowledge reduced execution miniscrew insertion planning time.
- Both Clinical Experience and Digital Knowledge had stronger importance in the first test than in the second, reflecting a loss in influence and the possibility, for an unexperienced clinician, to rapidly improve his capabilities and continuously reduce his mistakes, gaining on his more experienced colleagues.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Pre-test survey questions:

Clinical Experience: [(1) Do you have clinical or theorical experience regarding miniscrews placement for skeletal anchorage in orthodontics ?] [(2) How do you judge your knowledge about the use and placement of miniscrews as skeletal anchorage in orthodontics ?] [(3) Do you know the criteria for the correct placement of a miniscrew for orthodontic skeletal anchorage in palatal area?] [(4) Have you ever placed a palatal miniscrew?] **Digital Knowledge**: [(5) How do you evaluate your experience of digital planning of miniscrews ?] [(6) Have you ever planned a miniscrews insertion in the palatal area?] [(7) Have your ever used digital planning software for miniscrew's insertion in DICOM and STL file format?]

Appendix B

Post-test survey questions:

[(1) Have you used the same software previously to plan miniscrew insertion?] [(2) In which step did you encounter difficulty during the test?] [(3) Did you find your difficulty changed after the second test ?] [(4) Do you believe you have increased your knowledge about digital miniscrew insertion planning?] [(5) Do you think your skills increased after the two tests?]

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