Original Article

Accuracy of a dynamic guided surgery system for orthodontic miniscrew placement: an experimental in vitro study

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ABSTRACT

Objectives: To compare the accuracy and time required for orthodontic miniscrew placement using a dynamic computer-assisted surgery (d-CAS) system vs the conventional freehand (FH) approach. The effect of side, location, and operator experience was also evaluated.

Materials and Methods: A randomized, in vitro experimental study was conducted using 10 maxillary resin models. After virtual planning, 40 miniscrews were randomly placed by one experienced and one novice operator. Twenty miniscrews were placed using a d-CAS system (test group) and 20 using the conventional FH method (control group). Preoperative and postoperative cone beam computed tomography scans were superimposed to measure deviations between the planned and final miniscrew position, and placement time was recorded.

Results: The d-CAS group showed less deviation at the entry point (95% confidence interval [CI] = 1.79 mm to 0.16 mm; $P = .019$) and less angle deviation (95% CI = 8.5° to 1.7°; $P = .004$). No significant differences were observed in other variables. Both operators achieved similar accuracy. Placement time was significantly longer in the d-CAS group, with a mean difference of 6.3 minutes ($P < .001$).

Conclusions: Dynamic computer-assisted surgery improves the accuracy of orthodontic miniscrew placement vs the traditional FH method. However, d-CAS takes significantly longer. Clinician experience does not seem to significantly affect accuracy. (*Angle Orthod*. 0000;00:000–000.)

KEY WORDS: Computer-assisted surgery; Orthodontic miniscrews; Surgical Navigation Systems; Accuracy; Surgical experience

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Accepted: June 15, 2025. Submitted: February 14, 2025.
Published Online: July 14, 2025

INTRODUCTION

Adequate anchorage is crucial for orthodontic success. Currently, miniscrews are widely used as temporary anchorage devices because of their effectiveness and independence from patient compliance.[1–5] Nevertheless, miniscrews can damage roots or other anatomic structures.[1–5] Three-dimensional (3D) imaging such as cone beam computed tomography (CBCT) allows safer and more accurate insertion of these devices:[3,6] anatomic structures are more precisely located, while the force directions are better planned.[3,7]

In recent years, the use of digital technology has reduced the risk of complications during the placement of anchorage devices.[3–6,8] In this regard, computer-assisted surgery (CAS) seems a very useful tool, allowing the clinician to perform guided surgical procedures based on virtual planning;[9] either static or dynamic CAS (d-CAS) improves precision, accuracy, and efficiency when placing dental implants.[10–12] However, static CAS only allows limited intraoperative corrections, because the splint usually cannot be modified. In contrast, d-CAS provides real-time tracking of the position and angulation of the instruments, and corrections are much easier to perform.[10,12,13]

Dynamic CAS systems provide better accuracy and patient safety. Additionally, they do not require a custom-made splint.[7,12] Clinician experience and safety are very relevant issues: d-CAS reduces discrepancies in accuracy between experienced and novice operators,[7] improving safety in less experienced clinicians. However, the main limitations are the equipment cost, a steeper learning curve, and the need for registration and calibration processes, which might increase surgery time.[7,12,14]

Published data on the placement of orthodontic miniscrews using d-CAS are promising but still scarce.[15,16] As miniscrews are frequently placed in limited spaces between roots or close to anatomic structures, they carry the risk of damaging them.[5,8,17] Because d-CAS has been proven to be a very reliable tool to improve accuracy and precision in implant surgery,[3,7,11,13,18] this technology seems very promising for miniscrew placement. Thus, an in vitro study was designed with the aim of comparing the accuracy and time required for orthodontic miniscrew placement using d-CAS vs the conventional freehand (FH) method. The secondary aim was to assess the effect of miniscrew location and operator experience on accuracy and insertion time.

MATERIALS AND METHODS

Study Design

A randomized in vitro blinded experimental study was carried out, comparing orthodontic miniscrew placement with the Navident® dynamic navigation system (ClaroNav Technology Inc., Toronto, Canada; test group) vs FH insertion (control group). The Checklist for Reporting in vitro Studies (CRIS)[19] guidelines were followed whenever possible throughout the study, and an adaptation of the Consolidated Standards of Reporting Trials (CONSORT) flow chart was made.[20]

The G* Power version 3.1.9.6 package (Universität Kiel, Germany) was used to calculate sample size. According to a recent randomized clinical trial,[11] a 2.49 mm (SD $=$ 1.43) mean 3D apex deviation was expected when the FH approach is used. Considering that an improvement of 1 mm might be clinically significant in this scenario (placement of miniscrews in interproximal areas) and considering an allocation ratio of 1:1, $\alpha = 0.05$ and $1 - \beta = 0.8$, a sample of 40 miniscrews would be required.

Ten identical customized resin models (BoneModels, Castelló, Spain) placed in mannequin heads were used (Figure 1). Teeth were radiopaque, and upper premolars and molars had 3 mm between roots. Four miniscrews were planned in each hemiarch in similar positions between both premolars and both molars. The dimensions of the orthodontic miniscrews were 1.4 $\times$ 10 mm (diameter $\times$ length).

The orthodontic miniscrews were inserted in the models of the upper maxilla using two different approaches: 20 miniscrews were placed in five models with d-CAS (test group) and 20 were inserted in the other five models FH (control group). Ten miniscrews in each group were placed by a novice operator (fifth-year dental degree student, T.M.M.) and the rest by an oral surgeon with over 20 years of experience in oral surgery and implants (R.F.; Figure 2).

Models were randomized and allocated either to the test or control group. Additionally, the operated side (right or left) and miniscrew position (premolars or molars) were also randomized. To avoid bias related to the learning curve, a randomization sequence with blocks was employed. A random allocation sequence was generated using the website www.randomization.com by a third person not involved in orthodontic miniscrew placement or in measurement of the outcome variables (A.S.T.), and allocation information was placed in consecutively numbered opaque envelopes.

Virtual planning was performed before generating the allocation sequence. Before miniscrew placement, operators opened a numbered envelope, which disclosed allocation information (d-CAS or FH, miniscrew position, side, and surgeon). The measurements of all outcome accuracy variables were conducted by a calibrated researcher not involved either in the planning nor the surgical phase (A.J.G.).

Figure 1. Customized resin model employed in the study: partially edentulous maxilla with soft tissue and radiopaque roots and teeth.

The following outcome variables were registered (Figure 3):[21]

- Apex 3D deviation (mm): the deviation between the planned and final position of the implant apex in 3D of space (x, y, z).
- Entry two-dimensional (2D) deviation (mm): the deviation between the planned and final position of the implant platform in the x and y dimensions of space from the miniscrew head, without considering deviation in depth (z axis).
- Entry 3D deviation (mm): the deviation between the planned and final position of the implant platform in 3D of space (x, y, z).
- Apex depth deviation (mm): the vertical distance between the planned and final position of the implant apex (z axis).

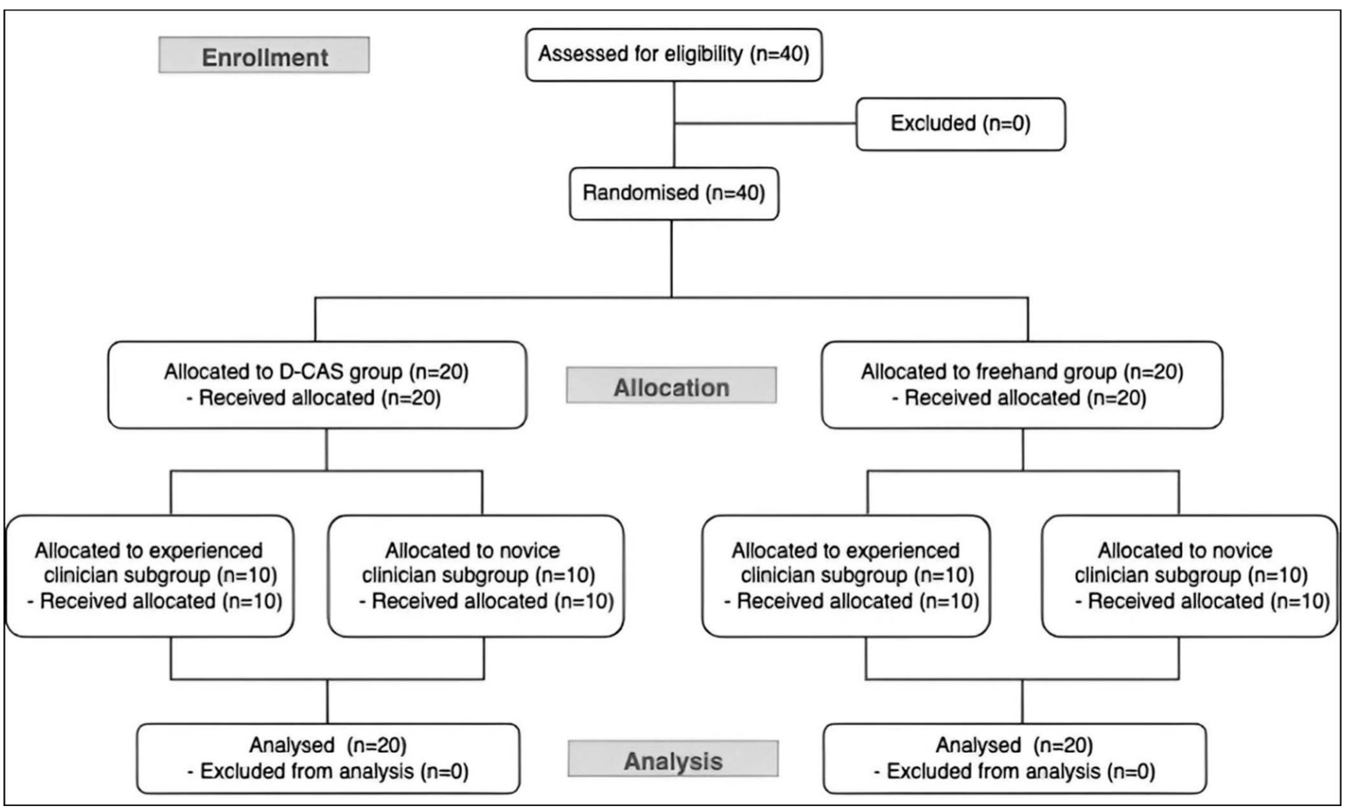

Figure 2. Adaptation of the CONSORT flow diagram (20). Forty miniscrews were randomized into two study groups (dynamic computer-assisted surgery and freehand), and then into two subgroups (experienced or novice operator).

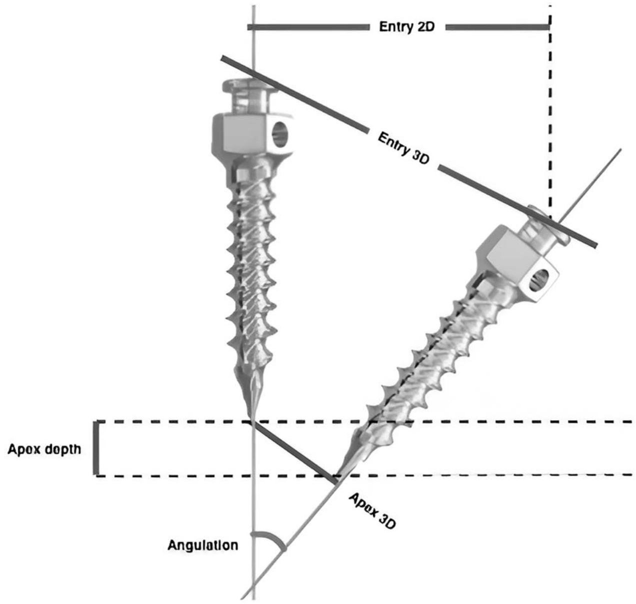

Figure 3. Description of the outcome variables.

- Angular deviation (°): the angular deviation between the central axes of the planned and final position of the implant.
- Placement time (min): the time required to place each miniscrew from the start of surgery until the final positioning of the device, including any additional time for necessary calibrations or checks.

Setting and Virtual Planning

A CBCT scan (Morita VERAVIEW X8000) of the models was performed with the following setup: 100 kV, 9.4 seconds, 1002.5 DAP (mGy·cm^2), 0.4 mm voxel. Additionally, all models were scanned using an intraoral scanner (3Shape TRIOS®).

Digital imaging and communication in medicine (DICOM) files of the CBCT scans and standard triangle language (STL) data from the intraoral scanners were uploaded to the navigation system software. After overlapping DICOM with STL, placement of the miniscrews was virtually planned in each model between the upper premolars and between the upper molars (T.M.M. and R.B.). The location was selected 9 mm from the gingival margin, avoiding the adjacent roots.

To replicate a real-life clinical scenario, the models were placed in a simulation phantom head in a dental chair (Figure 4).

Miniscrew Insertion and Measurements

In the d-CAS group, markerless pair-point tracing registration and calibration of the handpiece were made to locate the model and relate it with the miniscrew and the CBCT. After securely placing an optical marker (head tracker) on the phantom head, fiducial points were selected on the CBCT images and then traced on the model using a tracer tool to complete registration. Registration ended when the d-CAS

Figure 4. Simulation of a real clinical scenario, with the maxillary resin models placed in head mannequins.

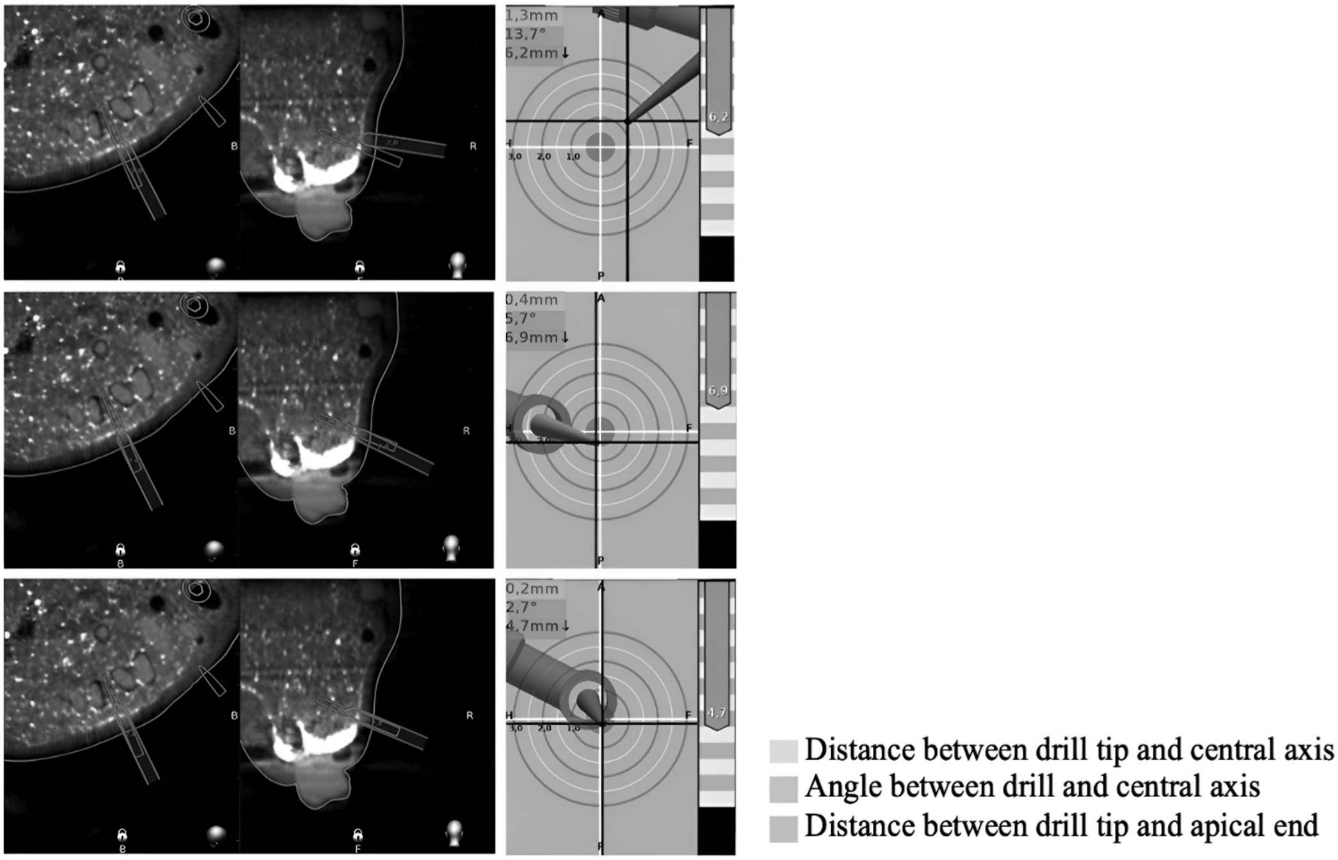

Figure 5. Navident software providing real-time guidance with cross-sectional views and target views.

gathered 100 points around each fiducial point. Then the handpiece axis and miniscrew length were calibrated with specific devices, and accuracy was checked. At this point, the miniscrew was placed in the position specified in the randomization envelope. The miniscrew was placed with real-time navigation since the Navident software continuously provided live guidance, displaying the planned miniscrew location and its current position on the screen (Figure 5).

In the control group, miniscrews were placed FH. Preoperative planning, technique (flapless surgery) and instruments (miniscrew attached to a contra-angle) were the same as used in the test group, with the only difference being that the surgeon did not have real-time guidance, although the CBCT was available for review before and during the procedure.

After placing all the miniscrews, a CBCT scan of each model was performed with the same equipment. The accuracy was assessed by a blinded investigator after superimposing the tow CBCT scans of each model and comparing the planned position with the real miniscrew location on the model. CBCT overlapping was performed using EvaluNav (ClaroNav Technology Inc.). Figure 6 summarizes the main steps of the study.

Statistical Analysis

A third blinded researcher conducted the statistical analysis using the Stata15.1 package (StataCorp, College Station, TX). The significance threshold for all statistical tests was established at $P < .05$.

Intraexaminer calibration was performed by measuring the superposition of 12 miniscrews and repeating this sequence after 15 days. The intraclass correlation indexes were 0.985 (entry 3D), 0.987 (entry 2D), 0.989 (apex 3D), 0.983 (apex depth), and 0.998 (angulation).

Bivariate analysis was done by Student *t*-tests for independent samples for scale accuracy variables with normal distribution. If normality was ruled out, a Mann-Whitney *U*-test was used. Specifically, interactions between the outcome variables and the following factors were analyzed: insertion methods (d-CAS vs FH), operator experience (experienced vs novice), and location of the miniscrew (premolar vs molar). A multiple linear regression model was developed. Interactions and potential confounding factors were evaluated to select the most efficient model that maximized the adjusted R^2 value. The final model was then tested for normality, variable independence, and collinearity.

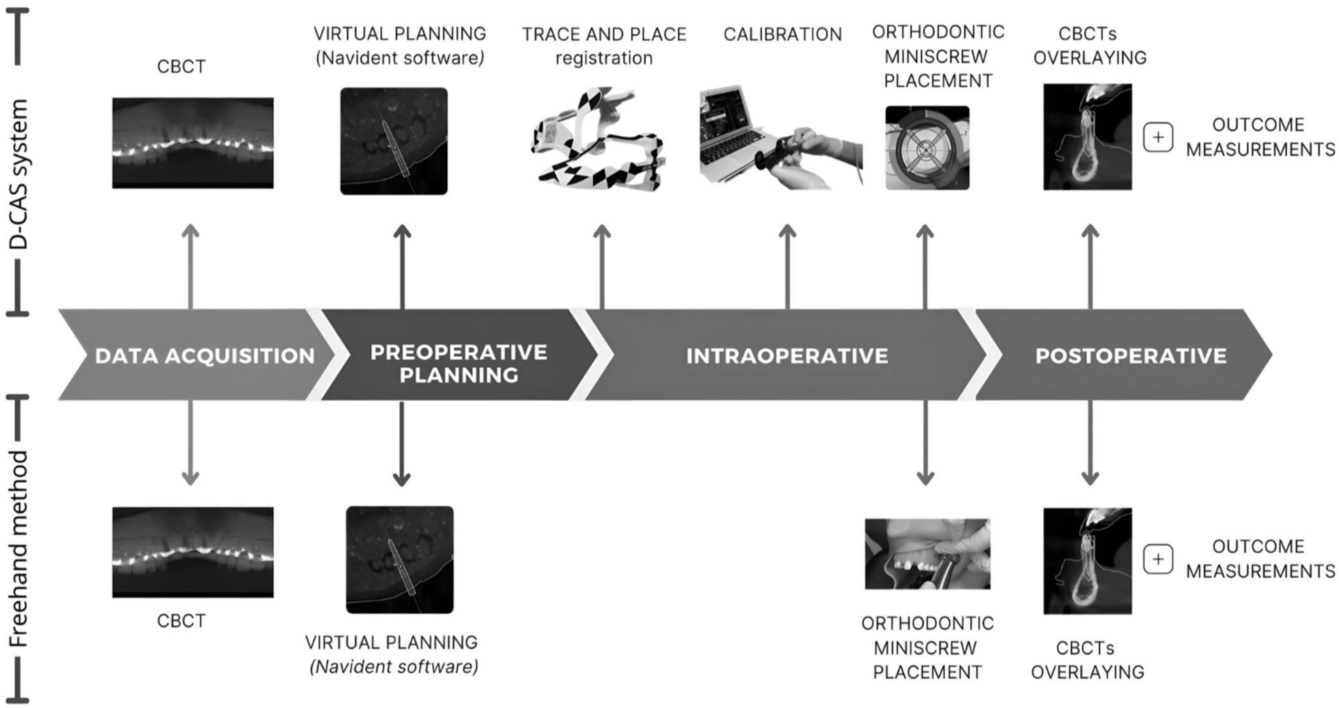

Figure 6. Study workflow.

RESULTS

The 40 orthodontic miniscrews had adequate primary stability. Overall, the d-CAS group showed lower mean deviations for all accuracy variables (Table 1; Figure 7). Entry 3D, entry 2D, and angulation were more accurate with d-CAS, the mean difference (MD) being 0.98 mm (95% confidence interval [CI] = 0.16 to 1.79; $P = .019$), 1.05 mm (95% CI = 0.21 to 1.89; $P = .024$), and 5.10° (95% CI = 1.72 to 8.50; $P = .004$), respectively (Table 1). In contrast, the placement time in this group was 6.3 min longer (95% CI = 4.4 to 8.1; $P \leq .001$).

In general, both operators (experienced and novice) yielded similar accuracy results (Table 2; Figure 7). The d-CAS system significantly improved entry 2D (MD = 1.49 mm; 95% CI = 0.003 to 2.98; $P = .049$) for the experienced surgeon, and angulation (MD = 6.48 mm; 95% CI = 0.79 to 12.17; $P = .027$) for the novice operator in comparison with the FH group. The surgical procedure was significantly longer for both clinicians with d-CAS ($P < .001$), but this difference was higher for the novice operator ($P = .014$).

On the left side, miniscrew placement was less accurate: in FH placement, side affected entry 2D and entry 3D, while in the d-CAS group, it influenced apex 3D (Table 3). No significant differences were found between d-CAS and FH in implants placed in the premolar area. However, in the molar region, significant differences in entry 2D and angulation were observed in favor of d-CAS (Table 3).

The multiple linear regression model results can be observed in Table 4.

Table 1. Differences in Outcomes (FH and d-CAS) Between the Two Study Groups[a]

	FH, mean ± SD, n = 20	d-CAS, mean ± SD, n = 20	Mean difference (95% CI), n = 40	*P* Value
Apex 3D (mm)	2.67 ± 1.4	2.29 ± 1.3	−0.38 (−1.24 to 0.48)	.397
Entry 3D (mm)[b]	3.1 ± 1.5	2.12 ± 1	−0.98 (−1.79 to −0.16)	.019*
Entry 2D (mm)[b]	2.93 ± 1.5	1.88 ± 1.1	−1.05 (−1.89 to −0.21)	.024*
Apex depth (mm)[b]	0.93 ± 0.7	0.62 ± 0.6	−0.31 (−0.70 to 0.08)	.113
Angulation (°)	11.91 ± 5.5	6.78 ± 5	−5.10 (−8.50 to −1.72)	.004*
Placement time (min)[b]	1.78 ± 0.9	8.04 ± 4.1	6.3 (4.4 to 8.1)	<.001*

[a] 2D indicates two-dimensional; 3D, three-dimensional; CI, confidence interval; d-CAS, dynamic computer-assisted surgery group; FH, freehand group; and SD, standard deviation.

[b] Mann-Whitney *U*-test.

* Statistical significance at $P < .05$.

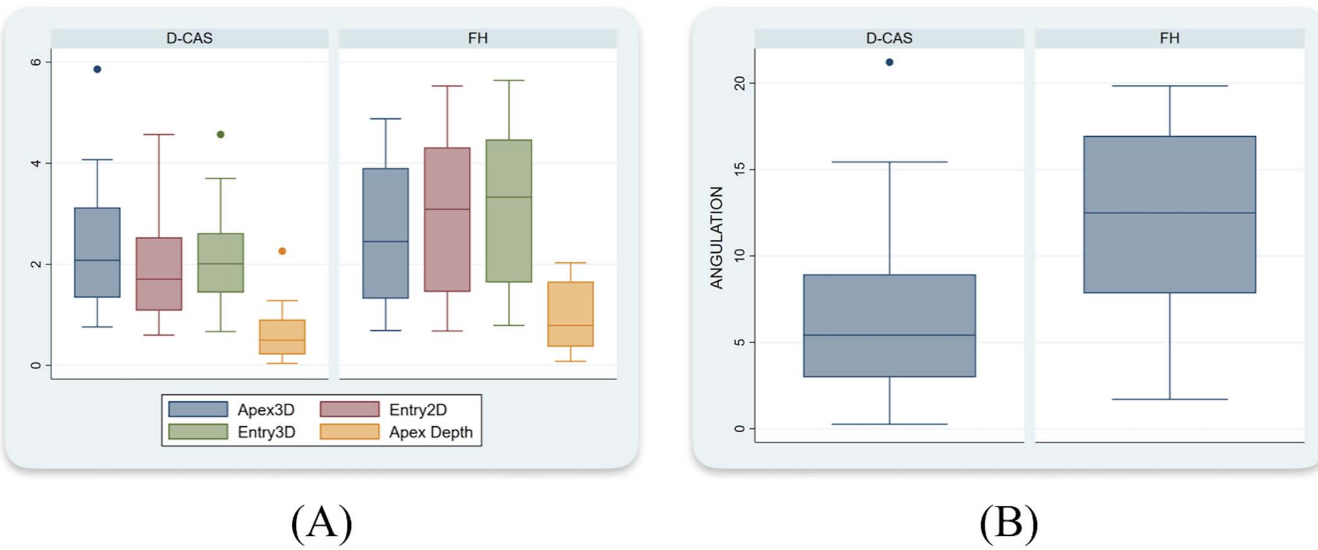

Figure 7. Box plots comparing the outcomes of the dynamic computer-assisted surgery (d-CAS) and freehand (FH) groups. (A) Linear two- and three-dimensional accuracy variables. (B) Angulation.

DISCUSSION

The conventional FH approach remains the most widely used technique among clinicians for placing miniscrews. Nevertheless, authors of a recent network meta-analysis showed that the use of static guided surgery provided greater accuracy in this procedure.[4] Unlike d-CAS, this option requires a customized surgical guide.

The findings of the present study indicated that d-CAS might improve the accuracy of orthodontic miniscrew placement in comparison with the FH approach.

Table 2. Differences in Outcomes (FH and d-CAS) Between the Two Study Groups, Comparing Operators (Novice and Experienced)[a]

	FH, mean ± SD, n = 20	d-CAS, mean ± SD, n = 20	Mean difference (95% CI), n = 40	*P* Value
Apex 3D (mm)				
Experienced	2.25 ± 1.1	2.75 ± 1.4	0.5 (−0.68 to 1.68)	.386
Novice	3.09 ± 1.6	1.83 ± 1.0	−1.26 (−2.53 to 0.01)	.052
P value	.115	.186	–	–
Entry 3D (mm)[b]				
Experienced	3.54 ± 1.7	2.25 ± 0.9	−1.29 (−2.71 to 0.12)	.082
Novice	2.65 ± 1.1	1.99 ± 0.7	−0.66 (−1.54 to 0.23)	.226
P value	.820	.289	–	–
Entry 2D (mm)[b]				
Experienced	3.40 ± 1.8	1.90 ± 1.4	−1.49 (−2.98 to −0.003)	.049*
Novice	2.47 ± 1.3	1.87 ± 0.7	−0.61 (−1.48 to 0.27)	.256
P value	.650	.850	–	–
Apex depth (mm)[b]				
Experienced	0.84 ± 0.6	0.74 ± 0.7	−0.10 (−0.68 to 0.48)	.570
Novice	1.02 ± 0.8	0.50 ± 0.4	−0.52 (−1.09 to 0.05)	.112
P value	.520	.705	–	–
Angulation (°)				
Experienced	11.49 ± 5.0	7.75 ± 4.1	−3.74 (−8.07 to 0.59)	.086
Novice	12.32 ± 6.3	5.84 ± 5.9	−6.48 (−12.17 to −0.79)	.027*
P value	.412	.746	–	–
Placement time (min)[b]				
Experienced	1.85 ± 1.3	5.91 ± 2.6	4.07 (2.14 to 5.99)	<.001*
Novice	1.73 ± 0.5	10.17 ± 4.2	8.44 (5.61 to 11.28)	<.001*
P value	.792	.014*	–	–

[a] In the mean difference column, signs have been preserved to describe 95% CI adequately. 2D indicates two-dimensional; 3D, three-dimensional; CI, confidence interval; d-CAS, dynamic computer-assisted surgery group; FH, freehand group; and SD, standard deviation.
[b] Mann-Whitney *U*-test.
* Statistical significance at $P < .05$.

Table 3. Accuracy Variables of the Two Study Groups Stratified by Operated Side (Right and Left Side) and Miniscrew Position (Premolars and Molars)[a]

Operated side and miniscrew position	Apex 3D (mm), mean ± SD, n = 40			Entry 3D (mm),[b] mean ± SD, n = 40			Entry 2D (mm),[b] mean ± SD, n = 40		
	FH, n = 20	d-CAS, n = 20	*P* Value	FH, n = 20	d-CAS, n = 20	*P* Value	FH, n = 20	d-CAS, n = 20	*P* Value
Right side	2.09 ± 1.3	1.79 ± 0.9	.574	2.83 ± 1.5	1.51 ± 0.6	.062	2.68 ± 1.5	1.17 ± 0.5	.020*
Left side	3.38 ± 1.2	2.70 ± 1.5	.277	3.41 ± 1.5	2.61 ± 1.0	.196	3.25 ± 1.6	2.46 ± 1.1	.209
P value	.126	.035*	–	.007*	.447	–	.005*	.424	–
Premolars	2.39 ± 1.5	2.65 ± 1.1	.667	2.9 ± 0.5	2.37 ± 0.8	.449	2.75 ± 1.4	2.12 ± 0.9	.256
Molars	2.96 ± 1.3	1.94 ± 1.5	.114	3.28 ± 1.6	1.87 ± 1.1	.063	3.12 ± 1.7	1.65 ± 1.2	.049*
P value	.235	.376	–	.130	.677	–	.173	.623	–

[a] 2D indicates two-dimensional; 3D, three-dimensional; d-CAS, dynamic computer-assisted surgery group; FH, freehand group; and SD, standard deviation.
[b] Mann-Whitney *U*-test.
* Statistical significance at $P < .05$.

Indeed, d-CAS was more accurate at the entry point and at angulation, particularly in posterior areas, where the access is more challenging. Since orthodontic miniscrews are usually placed in narrow spaces and in close proximity to the adjacent tooth roots and important anatomical structures (eg, the maxillary sinus or inferior alveolar canal), accurate placement is of utmost importance to avoid complications. Thus, d-CAS systems might be useful for this indication. It is important to note that, in this study, we primarily aimed at assessing deviations in the final position of the miniscrew in relation to preoperative planning. In this study, the selected entry point (9 mm from the gingival margin) may not be clinically feasible in all patients. However, the underlying principle is that, with accurate planning, the clinician is less likely to deviate from the intended insertion trajectory with d-CAS systems. Also, it is important to stress that these devices were originally designed for dental implant placement, so additional studies are necessary to assess their validity for orthodontic miniscrew placement.

Dynamic guided surgery increases the accuracy of dental implant placement in comparison with the conventional FH approach.[3,7,12,18,22] Indeed, in a meta-analysis, Jorba-Garcia et al.[21] evaluated nine navigation systems and recorded a mean angular deviation of less than 4° when using d-CAS. In other recent clinical trials,[14,23] this technology was also used successfully for dental implant placement. However, the available data were insufficient to determine whether these findings could also be extrapolated to other procedures such as orthodontic miniscrew placement.

Several variables such as CBCT resolution, preoperative planning, registration, tracking system precision, and the positioning, number, and type of fiducial markers might influence the accuracy results of computer-based dynamic navigation surgery.[23] These variables were standardized to increase the internal validity of the present study so their effect could not be assessed. While promising, given that d-CAS systems were originally designed for dental implant placement, additional studies are necessary to assess their validity for orthodontic miniscrew placement.

Miniscrews placed on the left side seemed to have higher deviations. The fact that both operators were right-handed could explain this result. However, the accuracy was also worse in the d-CAS group, which might reflect that, in some situations, the d-CAS system was unable to locate the handpiece optical marker for a few seconds due to the position of the operator.

The present results also seemed to show that d-CAS systems have a higher impact in posterior regions. Indeed, significant improvements in accuracy (entry 2D and angulation) were observed when the miniscrews were placed with the navigation system in the molar area. Accordingly, in a recent randomized clinical trial, greater differences were also found in dental implants inserted in the molar area.[11]

Dynamic CAS systems can either use a radiographic marker registration or markerless tracing registration process. In the present study, a markerless pair-point registration technique was used, eliminating the need for radiographic markers.[24] The device uses the head-tracker with optical markers (placed on the patient forehead) and the four landmark fiducials on tooth cusps in the CBCT image to perform automatic registration. Even though the markerless tracing registration method appears to improve the accuracy of dental implant placement compared with the radiographic marker registration method,[21] it has limitations: small movements of the head-tracker might induce inaccuracies, and therefore, the entire calibration process must be repeated. Thus, registration needs to be confirmed throughout the procedure by touching an anatomical landmark that can be seen on the screen. This could potentially explain the increased surgery time observed in the d-CAS group.

Table 3. Extended

Apex Depth (mm),[b] mean ± SD, n = 40			Angulation (°), mean ± SD, n = 40			Placement time (min),[b] mean ± SD, n = 40		
FH, n = 20	d-CAS, n = 20	*P* Value	FH, n = 20	d-CAS, n = 20	*P* Value	FH, n = 20	d-CAS, n = 20	*P* Value
0.95 ± 0.6	0.73 ± 0.7	.287	10.49 ± 4.8	4.96 ± 2.9	.007*	8.60 ± 3.6	1.94 ± 1.2	< .001*
0.90 ± 0.7	0.53 ± 0.4	.323	13.64 ± 6.1	8.30 ± 6.0	.064	7.58 ± 4.5	1.60 ± 0.5	< .001*
.594	.648	–	.142	.213	–	.588	.456	–
1.03 ± 0.7	0.66 ± 0.7	.226	11.45 ± 4.1	7.13 ± 5.7	.067	1.64 ± 0.6	7.92 ± 4.4	< .001*
0.84 ± 0.6	0.58 ± 0.4	.405	12.37 ± 6.9	6.47 ± 4.5	.036*	1.93 ± 1.3	8.17 ± 4.0	< .001*
.850	.570	–	.779	.721	–	.895	.525	–

Anatomical factors might also affect accuracy. Based on a recent prospective clinical study,[25] patients with a steep and high palatal vault may exhibit greater deviations when placing orthodontic miniscrews. Future researchers should determine whether the present findings can be extrapolated to other anatomical regions, such as the retromolar area.

The d-CAS systems have 2 major drawbacks: the cost of the equipment (over $50,000) and duration of the procedure. While both experienced and novice operators take longer with d-CAS than with FH, this difference was more substantial when unexperienced operators were involved. Authors of previous reports showed that navigated surgery has a learning curve,[7,12,21] and a higher success rate is expected in clinicians who have placed a minimum of 20 orthodontic miniscrews.[26]

Table 4. Coefficients, SEs, and 95% CIs of Multiple Linear Regression Models for the Accuracy Variables[a]

	Coefficient	SE	*P* Value	95% CI
Apex 3D				
Insertion method	1.33	0.39	.001*	0.55 to 2.11
Operator experience	−0.55	0.37	.147	−1.31 to 0.20
Miniscrew location	−0.03	0.17	.853	−0.38 to 0.32
Constant	1.56	0.87	.082	−0.21 to 3.33
Entry 2D				
Insertion method	1.47	0.40	.001*	0.65 to 2.29
Operator experience	−0.43	0.39	.281	−1.22 to 0.36
Miniscrew location	−0.01	0.18	.940	−1.04 to 2.67
Constant	0.82	0.91	.377	−1.04 to 2.67
Entry 3D				
Insertion method	0.11	0.43	.803	−0.76 to 0.98
Operator experience	0.17	0.41	.682	−0.67 to 1.01
Miniscrew location	0.53	0.19	.009	0.14 to 0.92
Constant	0.88	0.97	.370	−1.09 to 2.85
Apex depth				
Insertion method	0.38	0.20	.072	−0.03 to 0.79
Operator experience	−0.26	0.19	.191	−0.66 to 0.14
Miniscrew location	−0.10	0.09	.386	−0.26 to 0.10
Constant	1.02	0.46	.033	0.09 to 1.95
Angulation				
Insertion method	3.01	1.83	.109	−0.70 to 6.73
Operator experience	1.49	1.77	.405	−2.10 to 5.08
Miniscrew location	0.81	0.82	.329	−0.85 to 2.48
Constant	0.67	4.15	.873	−7.75 to 9.09

[a] 2D indicates two-dimensional; 3D, three-dimensional; CI, confidence interval; and SE, standard error.

* Statistical significance at $P < .05$.

This study has some limitations that should be considered. First, the in vitro design limited the external validity of the results. However, the models were realistic, and the use of a phantom head mimicked a real clinical scenario. Second, roots could not be palpated, which might explain the deviations observed in the entry point variables of the FH group. Third, only two operators were involved. Thus, future researchers should compare the outcomes of clinicians with different backgrounds (orthodontists, oral surgeons, general practitioners, among others) and degrees of experience.

CONCLUSIONS

- Dynamic computer-assisted surgery improves the accuracy of orthodontic miniscrew placement in the maxilla compared with the FH technique.
- However, miniscrew placement with d-CAS takes longer. Dynamic CAS systems might seem particularly useful when placing miniscrews in the molar area.
- Clinician experience does not seem to affect accuracy when placing miniscrews with d-CAS.

ACKNOWLEDGMENTS

The authors are grateful to Joe Perkins for English language editing assistance.

DISCLOSURES

This study did not receive any specific funding. The models were kindly provided by BoneModels (BoneModels®, Castellón de la Plana, Spain). Societat Catalana d'Odontologia i Estomatologia (SCOE; Barcelona, Spain) provided their facilities for the present study.

The authors declare that they have no known competing financial interests or personal relationships directly related with this study. However, they would like to declare the following interests outside the submitted work:

- Dr. Fernando Rojas-Vizcaya is the owner of BoneModels.
- Dr. Rui Figueiredo reports grants, personal fees, or non-financial support from MozoGrau (Valladolid, Spain), Avinent (Santpedor, Spain), Inibsa Dental (Lliçà de Vall, Spain), Dentaid SL (Cerdanyola del Vallés, Spain), Nobel Biocare (Zürich, Switzerland), Geistlich Pharma AG (Wolhusen, Switzerland), Araguaney Dental (Barcelona, Spain), Septodont (Saint-Maur-des-fossés, France), Laboratorios Silanes (Mexico city, Mexico) and Mundipharma (Cambridge, UK) outside the submitted work.
- Dr. Eduard Valmaseda-Castellón reports grants, personal fees, or non-financial support from MozoGrau (Valladolid, Spain), Avinent (Santpedor, Spain), Inibsa Dental (Lliçà de Vall, Spain), Dentaid SL (Cerdanyola del Vallés, Spain), Laboratorios Silanes (Mexico city, Mexico), Geistlich Pharma AG (Wolhusen, Switzerland) and Mundipharma (Cambridge, UK).

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