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Novel digital technique to analyze the accuracy and intraoperative complications of orthodontic self-tapping and self-drilling microscrews placement techniques: An in vitro study

Elena Riad Deglow,[a] Miriam O′Connor Esteban,[a] Álvaro Zubizarreta-Macho,[a,b] Sofía Hernández Montero,[a] Georgia Tzironi,[b] Francesc Abella Sans,[c] and Alberto Albaladejo Martínez[b]

Madrid, Salamanca, and Barcelona, Spain

Introduction: The objectives of this study were to analyze and compare the accuracy and intraoperative complications of orthodontic self-tapping and orthodontic self-drilling microscrew placement techniques. **Methods:** A total of 60 orthodontic microscrews were randomly distributed into 2 study groups: (1) group A, orthodontic self-drilling microscrew placement technique (n = 30); and (2) group B, orthodontic self-tapping microscrew placement technique (n = 30). Cone-beam computed tomography and intraoral scans were performed before and after the orthodontic microscrew placement techniques and uploaded in 3-dimensional implant planning software to analyze the deviation angle and the horizontal deviation measured at the coronal entry point and apical endpoint between orthodontic microscrews planned and performed, using the Student *t* test. In addition, intraoperative complications, such as root perforations after the orthodontic microscrews placement and the fracture of the orthodontic self-tapping microscrews during their placement, were also analyzed. **Results:** The paired *t* test revealed statistically significant differences at the apical endpoint ($P < 0.001$) between planned and performed orthodontic self-tapping and self-drilling microscrew placement techniques. However, the paired *t* test revealed no statistically significant differences at the coronal entry point ($P = 0.1047$) and angular deviations ($P = 0.3251$) between planned and performed orthodontic self-tapping and self-drilling microscrews placement techniques. Furthermore, 4 root perforations were observed at the orthodontic self-tapping microscrews placement technique, and 1 orthodontic self-tapping microscrew was fractured during the placement procedure. **Conclusions:** The results show that the orthodontic self-drilling microscrew technique increases the accuracy of orthodontic microscrews placement, resulting in fewer intraoperative complications. (Am J Orthod Dentofacial Orthop 2022;■:■-■)

In recent years, microscrews have been incorporated in orthodontics as temporary intraoral anchors to expand the therapeutic alternatives and perform complex movements.[1] Since Creekmore and Eklund[2] first placed a vitallium orthodontic screw in the anterior nasal spine to treat a patient with a deep overbite, orthodontic microscrews have been widely developed, introducing different characteristics and designs. Therefore, orthodontic microscrews have been recommended for inducing the maxillary suture expansion, correction of the dental midline, or the sagittal and vertical movement of the teeth.[3] Furthermore, the reduced size of the orthodontic microscrews allows its placement between the

[a]Department of Implant Surgery, Faculty of Health Sciences, Alfonso X El Sabio University, Madrid, Spain.
[b]Department of Surgery, Faculty of Medicine and Dentistry, University of Salamanca, Salamanca, Spain.
[c]Department of Endodontics, Universitat Internacional de Catalunya, Barcelona, Spain.
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Address correspondence to: Álvaro Zubizarreta-Macho, Department of Implant Surgery, Faculty of Health Sciences, Alfonso X El Sabio University, Madrid, Spain; e-mail, amacho@uax.es.
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root processes, providing a stronger anchorage compared with traditional anchorage devices and requiring less need for patient compliance.[4,5] In addition, orthodontic microscrews have evidenced a success rate between 85% and 80%[6]; however, the insertion and removal procedures may be traumatic to patients and should be lightly loaded after placement because there is a fibrointegration process around the orthodontic microscrews.[7] Furthermore, inaccuracy related to orthodontic microscrews placement can lead to intraoperative complications such as dental root contact, which can influence the survival of the nearby teeth regarding the dental tissues damage.[8] Therefore, it is highly relevant to plan the insertion site of orthodontic microscrews to prevent intraoperative complications accurately, especially root contact. Advanced radiographic techniques such as cone-beam computed tomography (CBCT) scans have been highlighted to analyze the optimal insertion site of orthodontic microscrews[9]; in addition, the preoperative planning by using specific dental planning software has influenced the accuracy of surgical procedures such as the position of dental implant placement[10] or the accuracy of endodontic microsurgery[11]; even to analyze the deviation rate of the endodontic access cavities.[12]

Currently, there are 2 types of orthodontic microscrews regarding the placement technique: (1) manually, with self-drilling orthodontic microscrews; and (2) mechanically with self-tapping orthodontic microscrews prior osteotomy of the cortical plate with an osteotomy pilot drill.[13] The cutting design of the tip of the self-drilling orthodontic microscrews allows the insertion of the orthodontic microscrews; however, the nonactive design of the self-tapping orthodontic microscrews requires the osteotomy of the cortical plate to allow its insertion into the bone.[13] The insertion site of orthodontic microscrews is usually recommended between the maxillary first and second premolars because it allows a simple and effective technique for the management of premolar extraction patients and also shows a high success rate (90.3%)[14]; however, the insertion site in the mandible has reported a lower success rate compared with maxillary because of the less vascularity and the higher bone density of the mandible, which may require the use of self-tapping placement technique to allow the penetration of the orthodontic microscrews through the mandible cortical plate.[15] Self-tapping orthodontic microscrews have been reported to have potential drawbacks such as pulp tissue damage, dental root contact, bur fracture, or overheating necrosis,[16] whereas manual placement of self-drilling orthodontic microscrews reduces bone damage working time and increase patient comfort.[13] However, it has been reported that self-tapping orthodontic microscrews can lead to lower bone microscrew contact and, therefore, a lower insertion torque, which influences the primary stability of orthodontic microscrews.[17]

This work aimed to analyze and compare the accuracy and intraoperative complications of orthodontic self-tapping and orthodontic self-drilling microscrew placement techniques, with a null hypothesis (H_0) stating that there would be no difference between the accuracy and intraoperative complications of orthodontic self-tapping and orthodontic self-drilling microscrew placement techniques.

MATERIAL AND METHODS

Eighty-four maxillary teeth representatives of all dental sectors, extracted for periodontal and orthodontic reasons, were selected in this study at the Dental Centre of Innovation and Advanced Specialties at Alfonso X El Sabio University (Madrid, Spain) between December 2019 and February 2020. A randomized controlled in vitro study was conducted after the principles defined in the German Ethics Committee's statement for the use of organic tissues in medical research (Zentrale Ethikkommission, 2003) and was authorized by the Ethical Committee of the Faculty of Health Sciences, University Alfonso X el Sabio (Madrid, Spain), in September 2019 (process no. 07/2019). All patients provided informed consent to transfer the teeth for the study.

The teeth were randomly (Epidat 4.1, Galicia, Spain) embedded into 6 experimental models of epoxy resin (EpoxiCure; Buehler, Lake Bluff, Ill) with 14 teeth each (2 maxillary central incisors, 2 maxillary lateral incisors, 2 maxillary canines, 2 maxillary first premolars, 2 maxillary second premolars, 2 maxillary first molars, and 2 maxillary second molars) with the Silicone Moulds System (KaVo Dental; Alcobendas, Madrid, Spain) placing each tooth parallel to each other following the longitudinal axis of the teeth, simulating a maxillary dental arch (Fig 1, *A*). The placing procedure of the teeth was performed by hand by an operator with 10 years of experience in orthodontics. The experimental models were randomly (Epidat 4.1) distributed to the following study groups: (1) group A, orthodontic self-tapping microscrew placement technique (n = 30); and (2) group B, orthodontic self-drilling microscrews placement technique (n = 30).

The experimental models of epoxy resin (EpoxiCure) were submitted to a 3-dimensional (3D) surface scan was performed with a 3D intraoral scan (True Definition; 3M ESPE, St Paul, Minn) using a 3D in-motion video imaging technology (Fig 1, *B*). Afterward, a preoperative CBCT scan (WhiteFox; Acteón Médico-Dental Ibérica

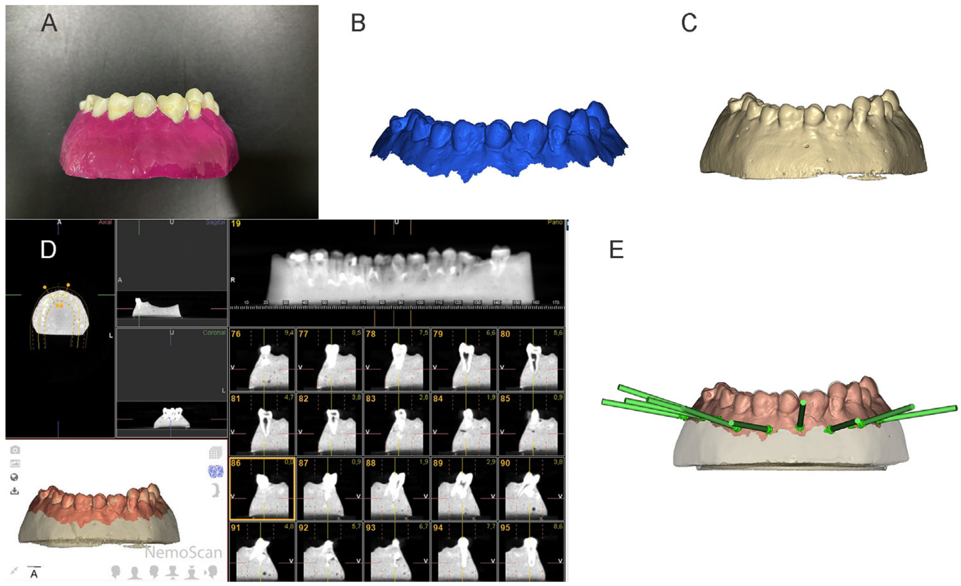

Fig 1. Digital workflow of the virtual planning of the ideal position of orthodontic microscrews. Epoxy resin model with embedded teeth **(A)**. Stereolithography digital file from the intraoral scanner **(B)**, 3D reconstruction **(C)** of the CBCT scan **(D)**, and virtually planned orthodontic microscrews **(E)**.

SAU-Satelec, Merignac, France) was performed with the following exposure parameters: 105.0 kVp; 8.0 mA; scan time, 7.20 seconds; and a field of view of 15 × 13 mm (Figs 1, *C* and *D*). Datasets obtained from the digital workflow were uploaded to 3D implant planning software (NemoScan; Nemotec, Madrid, Spain) to design the virtual placement of the orthodontic microscrews (Dual Top Anchor System; JEIL Medical Corporation, Guro-gu, Seoul, South Korea) of 1.6 mm diameter, 6.0 mm length active part and an inactive part of 2.3 mm by matching the 3D surface scan and CBCT data by aligning the key points of the crown of the teeth. Virtual orthodontic microscrews (Dual Top Anchor System) were placed to a depth of 6.0 mm, an insertion angle of 90° with respect to the longitudinal axis of the teeth, and a depth of 6.0 mm with respect to the cortical plate (Fig 1, *E*). Self-drilling orthodontic microscrew placement techniques (Dual Top Anchor System) were placed manually while self-tapping orthodontic microscrew (Dual Top Anchor System) placement techniques were placed after using an osteotomy pilot drill (Dual Top Anchor System). The orthodontic self-tapping (Dual Top Anchor System) and orthodontic self-drilling microscrews (Dual Top Anchor System) were placed by a unique operator, according to the recommendations performed by Cozzani et al.[18]

After placing the orthodontic self-tapping and orthodontic self-drilling microscrews (Dual Top Anchor System), postoperative CBCT scans (WhiteFox) were performed with the aforementioned described exposure parameters. Virtual orthodontic microscrews (Dual Top Anchor System) planned and postoperative CBCT scans (WhiteFox) of both orthodontic self-tapping and orthodontic self-drilling microscrews study groups were uploaded to the 3D implant planning software (NemoScan) and matched to analyze the deviation angle (measured in the center of the cylinder) and horizontal deviation (measured at the coronal entry point and apical endpoint) by an independent observer (A.A.M.) (Figs 2, *A-J*).

Root perforations after orthodontic self-tapping and orthodontic self-drilling microscrews (Dual Top Anchor System) placement were also analyzed and recorded at the 3D implant planning software (NemoScan) (Figs 3, *A-I*). In addition, the fracture of the orthodontic self-tapping and orthodontic self-drilling microscrews (Dual Top Anchor System) during their placement were also analyzed and recorded.

Statistical analysis

All variables of interest were recorded for statistical analysis with SPSS (version 22; IBM, Armonk, NY). Descriptive statistical analysis was expressed as means and standard deviation for quantitative variables. Comparative analysis was performed by comparing the mean deviation between planned and placed orthodontic self-tapping and orthodontic self-drilling microscrews placement techniques using Student t test because

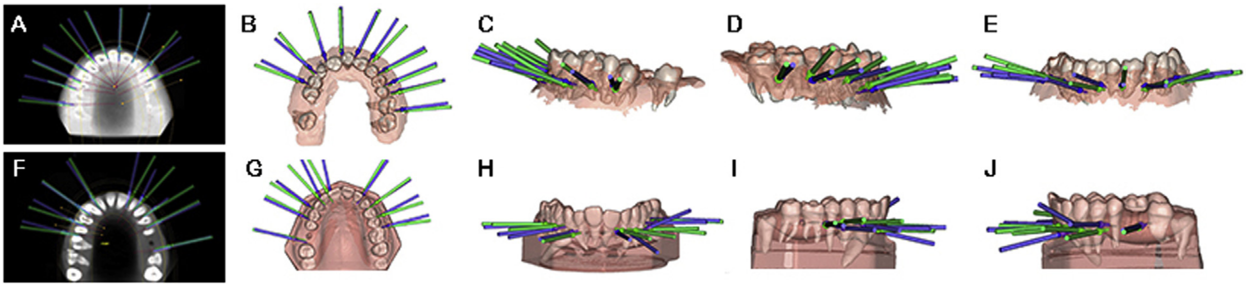

Fig 2. Deviations measurement procedure between planed (*green*) and performed (*blue*) orthodontic self-drilling **(A-E)** and orthodontic self-tapping microscrews study groups **(F-J)**.

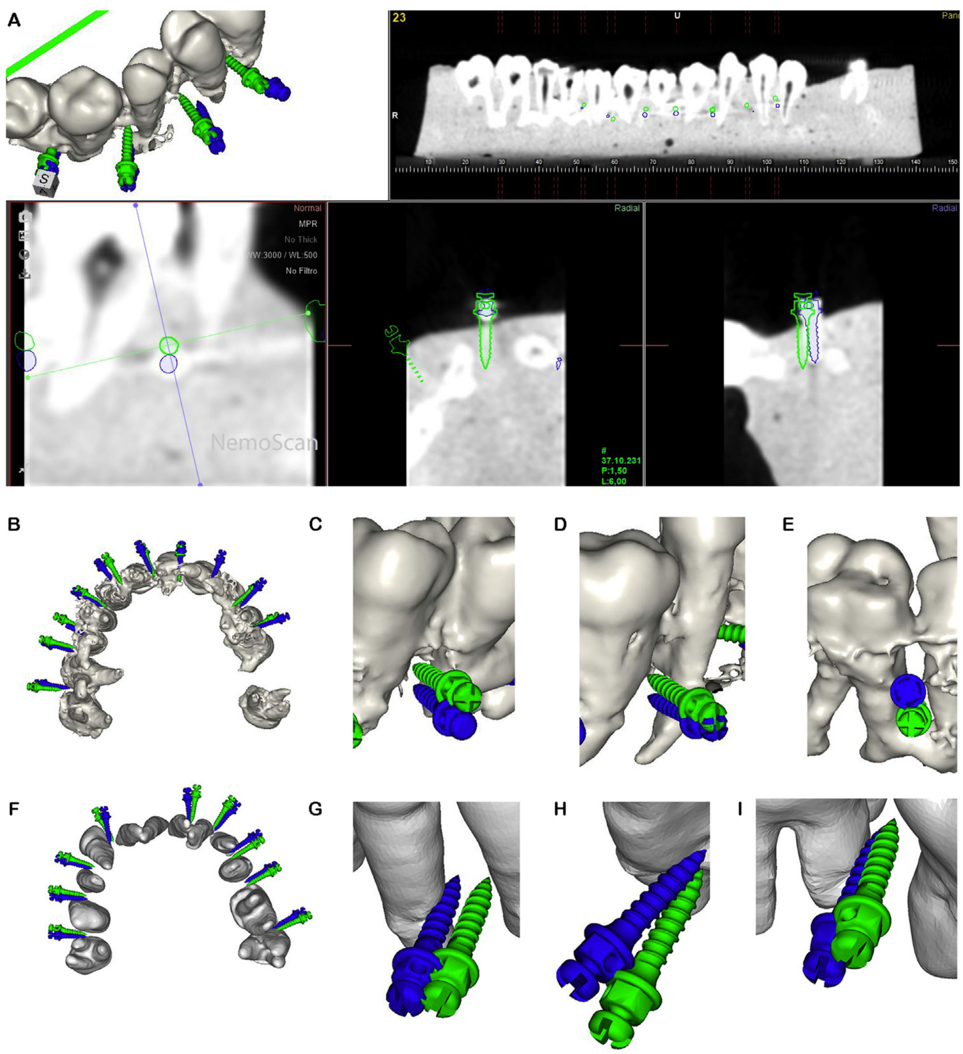

Fig 3. Root perforation analysis at the 3D implant planning software **(A)**. Perforation root process analysis between planed (*green*) and performed (*blue*) orthodontic self-drilling **(B-E)** and orthodontic self-tapping microscrews study groups **(F-I)**.

variables had normal distribution; $P < 0.05$ was considered statistically significant.

RESULTS

The means and standard deviation values for the coronal, apical, and angular deviation between the orthodontic self-tapping and self-drilling microscrew placement techniques are displayed in the Table.

The paired *t* test revealed no statistically significant differences at the coronal entry point deviations between planned and placed orthodontic self-tapping and orthodontic self-drilling microscrews study groups ($P = 0.1047$).

However, the paired *t* test revealed statistically significant differences at the apical endpoint deviations between planned and placed orthodontic self-tapping and orthodontic self-drilling microscrews study groups ($P < 0.001$).

The paired *t* test revealed no statistically significant differences at angular deviations between planned and placed orthodontic self-tapping and orthodontic self-drilling microscrews study groups ($P = 0.3251$).

Four root perforations were observed at the orthodontic self-tapping microscrews study group, and no root perforation was observed at the orthodontic self-drilling microscrews study group. In addition, 1 orthodontic self-tapping microscrew was fractured during its placement procedure.

DISCUSSION

The results obtained in the present study rejected the null hypothesis (H_0) that states that there would be no difference between the accuracy and intraoperative complications of orthodontic self-tapping and orthodontic self-drilling microscrew placement techniques.

The orthodontic microscrews used in the present study were selected because they allowed both manual and mechanical placement of orthodontic microscrews using orthodontic self-tapping and orthodontic self-drilling microscrews techniques, avoiding the need to introduce another orthodontic microscrew design that could influence the results of the study. The results obtained in this study showed a significantly higher accurate rate related to orthodontic self-drilling microscrews technique at apical endpoint (0.66 ± 0.23 mm), compared with self-tapping orthodontic microscrews (1.89 ± 0.58 mm). These results are highly relevant because the apical positioning of the orthodontic self-drilling microscrews influences the risk of root contact; thereby, the higher deviation of self-tapping orthodontic microscrews at apical endpoint could contribute to perforate 4 root processes while self-drilling microscrews did not produce root perforations. Root damage has been reported as one of the most frequently intraoperative complications during orthodontic microscrews placement. Although the extent of root processes damage by orthodontic microscrews depends on dental anatomy, the experience of the operator, as well as the technique used.[19] Specifically, dental root damage limited to the dental root surface (cementum or dentin) has shown a complete healing 12 weeks after orthodontic microscrews removal[20]; however, inflammatory infiltrate development and pulp invasion caused by orthodontic microscrews has shown to decrease the survival rate of the damaged tooth.[21] Although most severe damage caused to the dental root can influence the root fracture of the tooth, especially in the mandible, because of bone density.[22,23] Therefore, it is highly relevant to prevent root contact by orthodontic microscrews by analyzing the hardness of the surrounding anatomic structures during orthodontic microscrew placement because the different thickness and hardness values of the cortical plate, trabecular bone, periodontal ligament, cementum, and root dentin report the operator about the tissue type that the orthodontic microscrew go through across.[24,25]

The selection of the orthodontic microscrew should be based on radiographic planning regarding the cortical thickness and interradicular width of the insertion site, which also contributes to the prevention of orthodontic microscrew fractures.[26,27] In addition, the orthodontic microscrew outer and inner diameters are considered the most important factors for primary stability. However, other orthodontic microscrew designs (cylindrical vs conical, thread design) may affect primary stability and torsional fracture of orthodontic microscrews.[28] Small diameter orthodontic microscrews are an important risk factor for orthodontic microscrew fractures, especially at the insertion and removal procedures when fractures occur more frequently than when applying orthodontic forces. Although small diameter orthodontic microscrews have increased the risk of fracture, selecting orthodontic microscrews with diameters

Table. Descriptive deviation values at coronal (mm), apical (mm), and angular (°) levels the orthodontic self-tapping and the orthodontic self-drilling microscrews study groups

Location	*Study group*[1–29]	*n*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Coronal	Self-tapping	30	1.86	0.74	0.90	3.20
	Self-drilling	30	1.40	0.42	0.70	1.90
Apical	Self-tapping	30	1.89	0.58	1.20	2.90
	Self-drilling	30	0.66	0.23	0.40	1.20
Angular	Self-tapping	30	8.40	4.41	2.60	15.90
	Self-drilling	30	6.55	3.73	2.50	14.30

that are too large may lead to bone necrosis through microfractures in bone and root fracture.[29] Tip design of orthodontic self-drilling microscrews does not require an osteotomy pilot drill, except when the cortical plate is thicker than 2 mm. Furthermore, osteotomy pilot drills could also be used to decrease the insertion torque of orthodontic microscrews during initial placement, which positively prevents complications mentioned above, but result in less bone around the orthodontic microscrew. In addition, the mean failure rate of orthodontic microscrews still ranges between 14% and 17%. It is evident that the insertion angle and direction need to be monitored closely and maintained throughout the drilling procedure, regardless of the technique used. In many patients, the use of a surgical stent or an adjustable acrylic template might be helpful to guide the insertion and prevent complications.

CONCLUSIONS

Within the limitations of this in vitro study, the results show that the orthodontic self-drilling microscrew technique increases the accuracy of orthodontic microscrews placement, resulting in fewer intraoperative complications.

AUTHOR CREDIT STATEMENT

Elena Riad Deglow contributed to conceptualization, Miriam O'Connor Esteban contributed to methodology and software, Álvaro Zubizarreta-Macho contributed to conceptualization, Sofía Hernández Montero contributed to manuscript review and editing, Georgia Tzironi contributed to data curation, Francesc Abella Sans contributed to visualization, and Alberto Albaladejo Martínez contributed to conceptualization.

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