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ACCURACY OF CHAIRSIDE STATIC COMPUTER-ASSISTED FLAPLESS IMPLANT SURGERY FOR THE TREATMENT OF FULLY EDENTULOUS MAXILLAE: A RETROSPECTIVE OBSERVATIONAL STUDY

SDG 3

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Introduction

The treatment of fully edentulous dental arches with removable prostheses is particularly challenging due to the high frequency of patient complaints regarding adaptation and the inconveniences associated with their use [1]. Common issues include the need to remove the prosthesis for hygiene and sleeping, reduced masticatory efficiency, lack of retention and stability [2], and tactile or sensory impairment, leading many patients to seek implant-based alternatives [3]. Treatment with implant-supported complete dentures, however, requires complex surgical procedures that are associated with higher morbidity rates [4]. In addition, most patients undergoing such treatments are elderly, a population in which systemic diseases are comparatively more prevalent [5].

According to Chackartchi et al. [6], recent technological advances have enabled clinicians to incorporate computer-assisted design and computer-assisted manufacturing (CAD-CAM) techniques into clinical practice, allowing the acquisition of digitized information on bone, gingival, and dental structures, and transforming analog reverse planning into a fully digital workflow. Abduo et al. [7] noted that this computerized process allows for fully guided surgeries, in which drilling with surgical burs and implant placement are predetermined by computer software, offering greater predictability than freehand or partially guided techniques and enabling flapless procedures. Nonetheless, this technique entails additional costs, increased planning complexity, and the risk of errors associated with surgical guide stability and adaptation [8]. Moreover, most studies report the use of surgical guides produced by third-party planning centers, which further increases treatment costs [9]. In this context, the ability to perform digital planning and produce surgical guides directly in the clinician's office may help reduce costs, streamline the workflow, and facilitate broader adoption of guided surgery [9].

According to the literature, static computer-assisted implant surgery (sCAIS) employs surgical guides that can be supported by teeth, mucosa, or bone. Guide stability and implant placement accuracy progressively decrease from dental to mucosal and finally to bone support, and optimization often requires the use of fixation pins. In the maxillary arch, three anterior fixation pins are typically placed: one on the buccal aspect of the alveolar process on each side (left and right) and one centrally on the palatal aspect of the alveolar process. In their systematic review and meta-analysis, Moraschini et al. [10] identified only 5 studies reporting exclusively on maxillary cases, whereas Marlière et al. [11] and Azevedo et al. [12] included only 2 and 3 studies, respectively, under the same condition. The lack of consistency among these primary studies highlights the need for further investigation to provide reliable data on the effectiveness of sCAIS-based treatments in the maxillary arch. Therefore, the aim of this study was to evaluate the accuracy of sCAIS for flapless treatment of fully edentulous maxillae using chairside-generated surgical guides and to compare the results with accuracy levels reported in the literature for guides produced by third-party planning centers.

Literature Review

The lateral cervical, lateral apical, depth, and angular deviations observed following sCAIS for flapless treatment of fully edentulous maxillae using chairside-generated guides were significant ($p < 0.05$). However, except for depth deviation—where methodological differences in measurement reference points precluded a reliable comparison with the analyzed studies—the deviations were similar to or smaller than those reported in the literature for guides produced by third-party planning centers for edentulous maxillae [3,14–25]. These findings suggest that comparable outcomes can be achieved using a more streamlined and cost-effective workflow, even if it entails a longer learning curve [26].

Similarly, no significant differences were observed between anterior and posterior implants with respect to the measured deviations. This finding is consistent with the results of Verhamme et al. [27], but contrasts with other studies reporting greater deviations for posterior implants [15–17,22,25]. Vasak et al. [15] reported greater mesiodistal deviations for posterior implants, attributing this finding to increased gingival thickness in the posterior region. Di Giacomo et al. [16] also observed larger deviations in posterior implants, which they attributed to limitations in mouth opening—an issue not encountered in the present study. D'Haese et al. [17] linked larger deviations in posterior implants to lower bone density in the posterior maxilla, a condition not present in the current study, as 16 of the 18 patients had undergone bone augmentation procedures.

According to Cassetta et al. [20], 62% of deviations observed in sCAIS procedures are attributable to mechanical factors inherent to washers, surgical drills, and other components of the surgical kits, which require clearance to prevent mechanical interference that could displace the guides. In contrast, Vasak et al. [15], D'Haese et al. [17], and Feng et al. [25] attributed deviations to factors such as guide positioning, anesthesia, limited mouth opening, and alveolar ridge resorption.

Regardless of the relative contribution of each factor to implant deviations, Abduo et al. [7] emphasized that static surgical guides—whether tooth-, tissue-, or bone-supported—resulted in smaller discrepancies between planned and actual implant positions compared with freehand placement, despite the progressive reduction in precision associated with each support type.

Several clinical studies [10–12,16,17] have confirmed the accuracy of sCAIS; however, most included study groups combining partially and completely edentulous patients and guides with different types of support, without distinguishing between the dental arches involved. Few studies have focused exclusively on edentulous maxillae and employed flapless sCAIS [4,14,17,28]. Stübinger et al. [29] conducted a study solely on maxillae, but their procedures involved flap elevation, and the guides used were bone-supported, in contrast to the flapless, mucosa-supported approach applied in the present study.

Vasak et al. [15] measured cervical, apical, depth, and angular deviations in the buccolingual (BL) and mesiodistal (MD) directions for 86 implants placed in 18 patients, including both edentulous maxillae and mandibles. They reported cervical and apical deviations of 0.47 mm and 0.7 mm in the BL direction, and 0.45 mm and 0.59 mm in the MD direction, with an average angular deviation of 3.53°. Pettersson et al. [18] treated 25 patients, 15 of whom received maxillary complete dentures supported by 5 or 6 implants (totaling 89 implants), and observed mean deviations of 0.80 mm (range 0.10 to 2.68 mm) for lateral cervical, 1.05 mm (0.25 to 2.63 mm) for lateral apical, –0.06 mm (–1.65 to 2.05 mm) for depth, and 2.31° (0.24° to 9.96°) for angular deviations. The results of both studies were comparable to those obtained in the present study. However, in these studies, surgical planning was outsourced to Nobel Guide (Nobel Biocare AB, Gothenburg, Sweden) and Materialise (Materialise NV, Leuven, Belgium), respectively, which generally entails higher costs than chairside guide production.

D'Haese et al. [17] assessed the positioning accuracy of 78 implants placed using sCAIS in the fully edentulous maxillae of 13 patients and reported cervical, apical, and angular deviations of 0.91 mm (0.29–2.45 mm), 1.13 mm (0.32–3.01 mm), and 2.60° (0.16°–8.86°), respectively, with cervical and apical deviations slightly higher than those observed in the present study. These findings indicate that a chairside digital workflow can achieve results comparable to—and, for certain parameters, even superior to—those obtained through outsourced planning centers using proprietary software such as Mimics 9.0 (Materialise N.V.).

Di Giacomo et al. [16] placed 60 implants in partially and, predominantly, fully edentulous maxillae and mandibles using sCAIS, reporting cervical, apical, and angular deviations of 1.31 mm (0.09–2.69 mm), 1.79 mm (0.11–4.00 mm), and 6.53° (0.04°–18.64°), respectively. These values were higher than those observed in the present study, particularly for the maximum angular deviation (18.64° versus 12.13°), despite both studies employing a chairside digital workflow. A potential factor contributing to this discrepancy is the 3D printing technology used for the surgical guides—selective laser sintering (SLS)—which differs from the technology applied in the present study.

Vieira et al. [19] used sCAIS with a third-party planning center to place 62 implants in 14 patients with fully edentulous arches, including both maxillae and mandibles. In the maxillae, they reported cervical, apical, and angular deviations of 2.17 ± 0.87 mm, 2.86 ± 2.17 mm, and 1.93° ± 0.17°, respectively. Except for the angular deviation, which was notably smaller, these values were significantly higher than those observed in the present study.

Cassetta et al. [20] employed a third-party planning center to place 225 implants in patients with fully edentulous maxillae and mandibles using 28 static surgical guides, reporting cervical, apical, and angular deviations of 1.68 ± 0.6 mm, 2.19 ± 0.83 mm, and 4.67° ± 2.68°, respectively—values higher than those observed in the present study. However, methodological differences, including the inclusion of mandibular prostheses and the absence of fixation during sCAIS, preclude a reliable comparison with the present findings.

Despite differences in methodology for measuring and analyzing deviations, the available literature on sCAIS accuracy indicates a general convergence of results. Consistently, Yogui et al. [30] reported that implant survival rates following sCAIS are comparable to those observed with freehand placement, suggesting that the deviations associated with sCAIS do not pose significant technical challenges during the prosthetic phase after osseointegration.

Assessment of intra-examiner agreement for deviations between planned and actual implant positions using sCAIS indicated agreement for depth and angular measurements, but lack of agreement for lateral cervical and lateral apical measurements. These findings suggest that some of the observed discrepancies between planned and actual implant positions may be attributable to methodological factors. While this represents a limitation of the present study, it also highlights the potential for improving methods for measuring deviations in guided implant surgery, warranting further investigation.

In summary, guided surgical techniques for implant placement—whether using chairside-generated guides or outsourced services—offer benefits such as increased predictability and reduced surgical morbidity, particularly for patients in whom more invasive procedures are contraindicated. However, both approaches involve steeper learning curves, persistent deviations between planned and actual implant positions, and higher costs compared with freehand placement. The results of this study suggest that, from a cost perspective, the chairside approach may represent a favorable alternative to outsourced guide production while achieving comparable clinical outcomes.

Method

Study population

This study was conducted in accordance with the principles of the World Medical Association Declaration of Helsinki (2013). Access to the dental records of the included cases, containing patients' demographic data, tomographic scans, and digital files related to the initial and final implant positions, was authorized by the local research ethics committee (approval no. 7.316.235). All patients had provided informed consent for the use of their non-identifiable clinical data.

Eighteen patients (4 men and 14 women) aged 55 to 73 years, with completely edentulous jaws and wearing conventional removable complete dentures, sought treatment with implant-supported prostheses between 2019 and 2023. Sixteen patients had previously undergone grafting with xenogeneic biomaterial (BioOss Large; Geistlich Pharma, Wolhusen, Switzerland). Exclusion criteria included uncontrolled systemic diseases, poor oral hygiene, parafunctional habits, insufficient alveolar bone, psychological disorders, radiotherapy to the head and neck within the preceding six months, or intensive use of alcohol, tobacco, or other psychoactive substances.

Both the digital planning and surgical procedures were performed in a private clinic by the same experienced implantologist. Each patient received 6 to 8 implants, totaling 142 implants. The sample size was based on the systematic review by Azevedo et al. [12], in which the three studies including only fully edentulous maxillae reported an average of 109 implants. Considering an effect size of 0.25 and a significance level of 0.05, the 142 measurements for each of the four types of deviations provided a statistical power of 0.848. Sample size calculations were performed using G*Power v. 3.1.9.4 [13].

Digital planning

All patients had their complete dentures relined with a polyether-based material (Impregum; 3M Company, Saint Paul, MN, USA) to ensure proper adaptation to the underlying mucosa, thereby optimizing surgical guide accuracy. Cone-beam computed tomography (CBCT) images were acquired using a CT scanner (Carestream CS 8100; Carestream Health, Rochester, NY, USA) set at 90 kV, 8-cm field of view, 14-s exposure time, and 0.150-mm voxel size. The double scan technique was employed to generate patient records: the first scan was of the relined denture alone, with gutta-percha markers (Dentsply Sirona, Charlotte, NC, USA), and the second scan was of the patient wearing the denture in habitual occlusion, without any additional record or bite guide. Digital implant planning was performed using dedicated software (Blue Sky Plan 4; Blue Sky Bio, Libertyville, IL, USA), with superimposition of the bone and prosthesis scans guided by the gutta-percha markers.

Each patient received 6 to 8 indexed Morse taper implants (BioFit; DSP Biomedical, Campo Largo, PR, Brazil) in the maxillary arch: 2 anterior and 4 posterior implants in cases with 6 implants, and 4 anterior and 4 posterior implants in cases with 8 implants. In all cases, three anterior fixation pins were placed: one on the buccal aspect of the alveolar process on each side, positioned between the lateral incisor and first premolar regions, and one centrally on the palatal aspect of the alveolar process, positioned to avoid the nasopalatine foramen. The surgical guide was produced chairside using a 3D printer (LCD Photon; Anycubic, Hong Kong, China), acrylic resin (High Clear; Anycubic), and curing and post-processing equipment (Wash and Cure; Anycubic).

Surgical procedure

The surgeries were performed under local anesthesia. The surgical guide was stabilized by digital pressure, and its adaptation was verified through clinical inspection. Once proper adaptation was confirmed, the guide was secured using 3 pins at the predetermined locations. Surgical alveoli were prepared through the guide’s holes without the use of metal washers. Drill guides were employed for osteotomy, following the manufacturer’s instructions for the guided surgery kit used (BioFit; DSP Biomedical, Campo

Largo, PR, Brazil). Implant diameters were standardized at 3.5 mm, while lengths were adjusted according to the requirements of each site. Implants were maintained subgingivally with healing caps to permit continued use of the patient's existing prosthesis during the osseointegration period. Postoperative CBCT scans were acquired immediately after surgery.

Measurement of implant deviations

Pre- and postoperative scans were manually superimposed using Blue Sky Plan 4 v. 4.9.4.2 software (Blue Sky Bio) to compare the planned and actual positions of the implants. This process involved marking and superimposing at least five anatomical landmarks on the anterior nasal spine, posterior nasal spine, infraorbital foramina, lateral laminae of the pterygoid processes, and zygomatic processes. Each implant was evaluated in the tangential section showing the greatest positional discrepancy, and lateral cervical (mm), lateral apical (mm), depth (mm), and angular (°) deviations were measured (Figure 1).

Statistical analysis

The Wilcoxon test was applied to assess intra-examiner agreement. For this purpose, tomographic superimpositions of 40 implants were randomly selected, anonymized by an independent researcher, and re-measured for comparison. The one-sample Student's t-test was used to evaluate differences between the planned and actual implant positions. The Mann-Whitney test was employed to compare anterior and posterior implants with respect to the observed deviations. A significance level of 5% was adopted..

Results or Expected Results

The deviation values for implants placed using sCAIS are presented in Table 1. Significant differences were observed between the planned and actual implant positions for all four types of deviations analyzed ($p < 0.05$).

Table 1 – Deviations between planned and actual implant positions using sCAIS

	Angular deviation	Depth deviation	Lateral apical deviation	Lateral cervical deviation
Mean	2.875	0.676	0.957	0.657
Median	2.450	0.580	1.010	0.620
Standard deviation	1.951	0.539	0.514	0.355
Q1	1.450	0.330	0.560	0.430
Q3	3.670	0.890	1.310	0.820
N	142	142	142	142
95% CI	0.322	0.089	0.085	0.059
Lower limit	2.553	0.587	0.873	0.598
Upper limit	3.197	0.765	1.042	0.716
p-value	< 0.001	< 0.001	< 0.001	< 0.001

sCAIS: static computer-assisted implant surgery; Q1: first quartile; Q3: third quartile; 95% CI: 95% confidence interval. One-sample Student's t-test ($p < 0.05$).

A comparison of deviation values between anterior and posterior implants placed using sCAIS is presented in Table 2. No significant differences were observed between anterior and posterior implants with respect to planned versus actual positions (p > 0.05).

Table 2 – Comparison of observed deviations between anterior and posterior implants installed using sCAIS.

	Angular deviation		Depth deviation		Lateral apical deviation		Lateral cervical deviation	
	A	P	A	P	A	P	A	P
Mean	2.696	3.057	0.603	0.751	0.912	1.004	0.655	0.659
Median	2.290	2.515	0.510	0.610	1.010	1.005	0.620	0.620
Standard deviation	1.596	2.252	0.424	0.629	0.475	0.550	0.326	0.384
Q1	1.405	1.710	0.300	0.338	0.560	0.525	0.435	0.388
Q3	3.675	3.593	0.795	1.033	1.235	1.440	0.800	0.890
N	72	70	72	70	72	70	72	70
95% CI	0.371	0.527	0.099	0.147	0.110	0.129	0.076	0.090
p-value	0.557		0.246		0.346		1.000	

sCAIS: static computer-assisted implant surgery; A: anterior implants; P: posterior implants; Q1: first quartile; Q3: third quartile; 95% CI: 95% confidence interval. Mann-Whitney test (p < 0.05).

The intra-examiner agreement for measurements of deviations between the planned and actual positions of implants placed using sCAIS is presented in Table 3. The results indicate agreement for depth and angular deviation measurements, whereas lateral cervical and lateral apical deviations showed a lack of agreement.

Table 3 – Intra-examiner agreement for measurements of deviations in implants installed using sCAIS.

	Angular deviation		Depth deviation		Lateral apical deviation		Lateral cervical deviation	
	T	RT	T	RT	T	RT	T	RT
Mean	1.995	2.098	0.425	0.540	0.540	0.540	0.686	0.899
Median	1.915	1.895	0.360	0.450	0.755	1.035	0.655	0.810
Standard deviation	0.900	0.970	0.249	0.406	0.482	0.675	0.330	0.550
N	40	40	40	40	40	40	40	40
95% CI	0.279	0.301	0.077	0.126	0.149	0.209	0.102	0.170
p-value	0.489		0.084		0.001		0.004	

sCAIS: static computer-assisted implant surgery; T: test; RT: retest; 95% CI: 95% confidence interval. Wilcoxon test ($p < 0.05$).

Conclusions or Final considerations

Although significant, the lateral cervical, lateral apical, and angular deviations between planned and actual implant positions using sCAIS were comparable to or smaller than those reported for guides produced by third-party planning centers. No significant differences were observed between anterior and posterior implants in terms of the measured deviations.

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