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Comparing Medium to Long-Term Esthetic, Clinical, and Patient-Reported Outcomes Between Freehand and Computer-Assisted Dental Implant Placement: A Cross-Sectional Study

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ABSTRACT

Objective: The aim of the study was to compare medium to long-term clinical and patient-reported outcomes between implants placed with computer-assisted implant surgery (CAIS) and freehand protocols.

Materials and Methods: Thirty dental implants in the anterior maxillary region with an average of 4 years after loading were assessed by means of Pink Esthetic Scores (PESs), marginal bone level (MBL), and clinical and patient-reported outcomes.

Results: CAIS significantly outperformed freehand placement with regard to PES scores ($p = 0.011$). Likewise, implants placed with CAIS showed significantly higher MBLs ($p < 0.001$). Bleeding on probing, probing depth, and prevalence of mucositis did not differ between the groups, while no peri-implantitis was diagnosed.

Conclusions: The use of CAIS leads to superior outcomes in terms of esthetics and MBLs for implants placed in the esthetic zone as observed in medium to long-term follow-up. No difference was however observed with regard to peri-implant mucosa inflammation.

Clinical Significance: This article highlights the outcome of computer-assisted implant surgery in achieving higher esthetic, MBL, and esthetic satisfaction compared to freehand implant placement.

Thai Clinical Trial Registry: TCTR20240422015.

1 | Introduction

Clinical success with implant therapy is currently defined as a multidimensional condition, extending to tissue health and stability, esthetics, function, and patient satisfaction [1]. Several factors have been suggested to influence the medium to long-term success of implant therapy, from local anatomic conditions [2], patient's systemic conditions and risks [3], the prosthesis design [4], the practice of oral hygiene, as well as behavioral factors [5, 6], all of which have been assessed by different outcome measures. The design of the implant prosthesis in particular and consequently the implant three-dimensional position have been shown in recent studies to hold significant influence over medium to long-term clinical outcomes, both with regards to esthetics, as well as risk for mucositis [7] and peri-implantitis [8]. Malposition of the implant has been often cited as a common predisposition to both technical and biological complications [9]. Thus, the modern digital

paradigm of implant therapy is focused on the design of an implant prosthesis complex in full harmony with the patient's individual anatomy, ensuring the best possible conditions for tissue health and stability, accessibility to oral hygiene, and esthetics. The precise implant placement in the optimal and pre-determined position remains a prerequisite for the transfer of the optimal prosthesis from the computer-aided plan to the actual patient's anatomy, and thus computer-assisted implant surgery (CAIS) has recently acquired a key role in the modern design-driven and digital workflow [10].

CAIS is at present widely available by means of two digital technologies, namely static and dynamic. Both systems require detailed pre-surgical computer-assisted design (CAD) of the implant and prosthesis. Thereafter, the static workflow utilizes 3D-printed surgical guides to secure the implant placement in the planned position, while the dynamic achieves this by means of real-time intraoperative feedback to the surgeon through a navigation device. Both techniques can significantly reduce the deviation of the implant from the planned position as compared to freehand placement [11], albeit not completely eliminate it. This way CAIS could potentially prevent complications such as mandibular nerve damage, sinus perforations, fenestrations, dehiscence, and adjacent tooth root damage while also reducing the occurrence and extent of malposition and the associated risks for the long-term success of implant therapy.

Despite however extensive documentation of the increased accuracy, research on the impact of CAIS on medium to long-term clinical outcomes is scarce, and the expectation of reducing risks and increasing outcomes related to tissue health and esthetics is yet to be substantiated by evidence [11]. The same is true for patients' perceptions and experience, as the assessment of patient-reported outcomes in relation to the use of CAIS has been relatively scarce and mainly focused on the short term [12].

The aim of this cross-sectional study was to assess the influence of the use of CAIS in the medium to long-term clinical outcomes with regard to tissue stability and health, esthetics, and patient satisfaction, as compared to implants placed freehand. A secondary exploratory aim of the study was to investigate potential differences in the same outcomes between the use of static and dynamic CAIS.

2 | Materials and Methods

This cross-sectional study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2023–021) and was registered at the Thai Clinical Trials Registry (TCTR20240422015). This study was conducted in accordance with the STROBE guidelines for reporting cross-sectional studies. Patients consecutively scheduled for their annual follow-up examination at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University between 1st May 2023 and 31st January 2024 were invited to participate in the study if they fulfilled the following criteria.

Inclusion Criteria:

- Single, bone-level implant, placed in the anterior Maxilla,
- Implant placed with Freehand or CAIS (d-CAIS/s-CAIS fully guided protocol).
- Implant restored with a single crown.
- Available for clinical and radiographic examination at least 1 year after loading.

Upon written informed consent and fulfillment of the inclusion criteria, patients were enrolled in the study.

Exclusion Criteria:

- Implants placed in fresh extraction sockets and/or implants immediately restored.
- Patients unable to comply with the study instructions.

2.1 | Sample Size Calculation

Sample size calculation was conducted via statistical software (G*Power software, version 3.1) using a *t*-test, mean: Wilcoxon–Mann–Whitney test (two groups) with 95% study power and a significance level (α) set at 0.05. The effect size was calculated based on a previous study by Fürhauser et al. [13]. To estimate the sample mean, Luo's study [14] was followed, and the standard deviation (SD) was based on Wan's study [15]. The minimum total sample size required for the primary objective was 20 patients which was divided into two main categories: CAIS 10 and Freehand 10. In order to pursue an additional exploratory analysis for possible differences in outcomes between static and dynamic, the sample of CAIS was increased to 20 (10 static and 10 dynamic). However, a valid sample size calculation was not possible for this part due to the absence of any published data in this question.

2.2 | Examination Protocol

2.2.1 | Clinical Examination

All patients underwent clinical and radiographical examination, as directed by the maintenance protocol for patients with dental implants of the department. This included:

- Visual inspection for signs of inflammation (redness, swelling)
- Dichotomous registration (Yes/No) of bleeding on probing and probing depth at six sites with plastic periodontal probe (12-UNC COLORVUE; Hu-Friedy, Chicago, IL, USA)
- Standardized periapical radiograph with parallel cone technique and perpendicular beam to the implant axis
- Standardized clinical photography of all anterior maxilla teeth with a digital camera (Sony A7 Mark III; Sony, Tokyo, Japan), using a Macro lens (AF Micro-Sony 90 mm f/2.8D; Sony) and a dual-point flash, including the treated implant and contralateral teeth.
- Gingival biotype (GB) of the peri-implant mucosa was assessed through direct visual assessment with a periodontal probe and direct measurements as described by

Kan et al. [16] Biotype was classified as thick or thin (Figure 1).

2.2.2 | Pink Esthetic Score

Standardized clinical photographs were taken according to previously published protocol [17]. The protocol for assessment of Pink Esthetic Score (PES) was defined by Fürhauser in 2005 as an esthetic analysis method to evaluate seven variables related to the mucosal tissue around implant prostheses [18]. In brief, the assessment was conducted twice to confirm the examiner's scoring reliability, and scores were consequently further analyzed statistically. The assessed variables included mesial papilla, distal papilla, soft tissue level, soft tissue shape, deficient alveolar process, soft tissue color, and soft tissue texture (Figure 2). Each variable was scored on a scale from 0 to 2, where 0 indicates a poor result and 2 represents a perfect score. The maximum total score achievable in the PES analysis is 14 "perfect." The threshold for clinically acceptable esthetic outcome was set at 8. Additionally, implants with a score of 12 or higher were grouped as "almost perfect" [19].

Assessment of the PES was performed twice, within a 4-week interval by one trained examiner, blinded to the method of placement of each implant. The agreement between the two assessments was assessed using the ICC test.

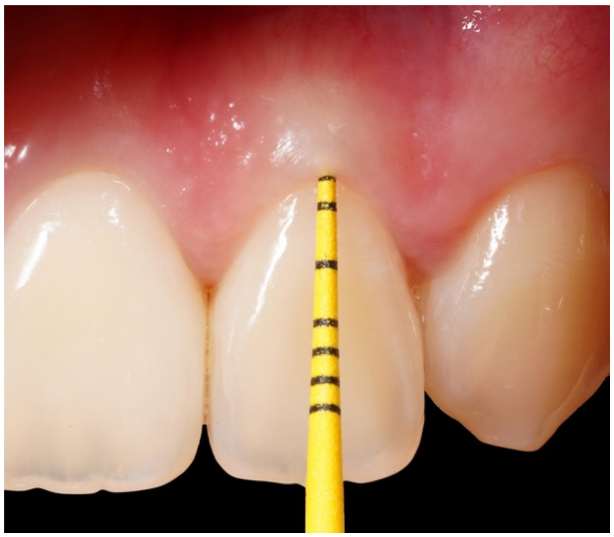

FIGURE 1 | Gingival biotype assessment (thick/thin) by means of plastic, colored periodontal probe.

2.2.3 | Marginal Bone Level

Periapical radiographs obtained using the long cone paralleling technique during the follow-up examination were analyzed using Image J software (Image J, NIH, Montgomery County, MD, USA) to identify the vertical peri-implant marginal bone level (MBL). A line parallel to the implant's prosthetic connection was drawn at the implant shoulder, and another line was drawn vertically from the implant shoulder to the point of first contact with the bone, where the MBL was defined (Figure 3). All measurements were conducted by one trained examiner at the mesial and distal of each implant in millimeters. All measurements were calibrated based on the known length of the implant. In cases where the implant appeared in tight contact with peri-implant in its entire length or bone level appeared more coronal than the implant shoulder, a value of "0" was assigned [20].

2.2.4 | Case Definitions of Peri-Implant Tissue Conditions

2.2.4.1 | Peri-Implant Health. Based on the 2017 World Workshop (Berglundh et al. [21]), a diagnosis of peri-implant health was defined as the absence of clinical signs of inflammation, no bleeding or pus upon gentle probing, and no bone loss beyond the crestal bone level changes attributed to initial bone remodeling.

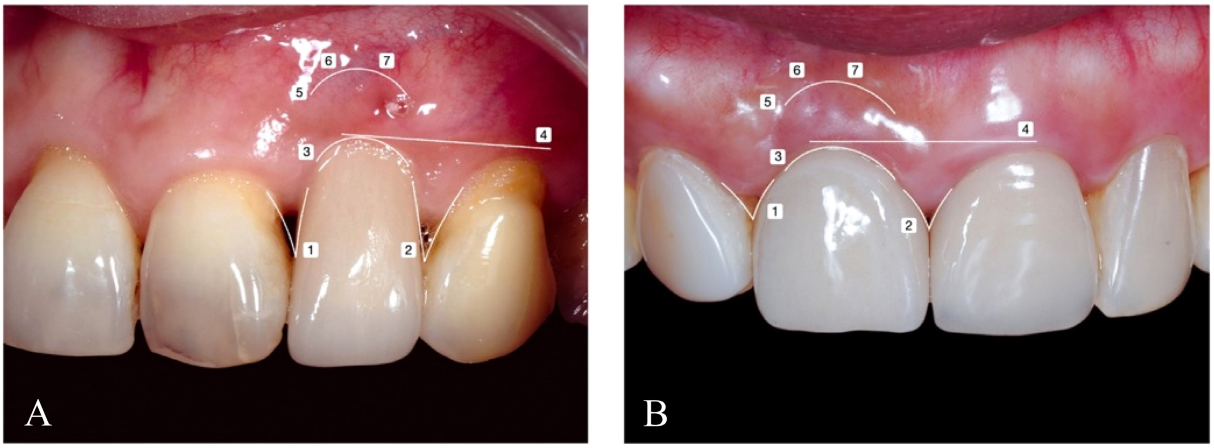

FIGURE 2 | Examples of (A) low and (B) high Pink Esthetic Scores, assessed by means of intra-oral photograph. (1) Mesial papilla, (2) distal papilla, (3) soft tissue level, (4) soft tissue shape, (5) deficient alveolar process, (6) soft tissue color, and (7) soft tissue texture.

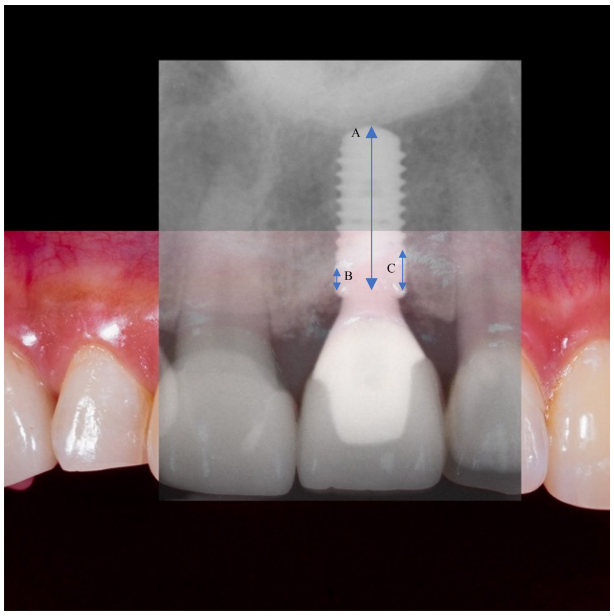

FIGURE 3 | Marginal bone level measurement: (a) implant length, (b) MBL at mesial, MBL at distal.

2.2.4.2 | **Peri-Implant Mucositis.** The case definition of mucositis was based on 2017 World Workshop (Berglundh et al. [21]), as the presence of bleeding and/or pus on gentle probing and no bone loss beyond what is anticipated due to remodeling.

2.2.4.3 | **Peri-Implantitis.** Prevalence of peri-implantitis was defined with the case definition by Berglundh et al. [21] for observational/epidemiological studies (bone levels ≥ 3 mm apical of the most coronal portion of the intra-osseous part of the implant combined with bleeding on probing) [21].

2.2.5 | Patient Satisfaction

The patients' satisfaction was assessed by means of a five-item questionnaire, three of which (function, comfort, esthetics) were assessed in a 5-point Likert scale from "very satisfied" to "not at all satisfied" and two as dichotomous (food impaction, use of the dental floss) [22].

2.2.6 | Statistical Analysis

All data were inserted into a spreadsheet (Excel, Microsoft Corp., Redmond, WA, USA). Statistical analysis was performed using SPSS software (version 28; SPSS Inc., Chicago, Illinois, USA). A descriptive analysis of all variables was performed. The Shapiro–Wilk test was utilized to test the presence of a normal distribution of the data, and a non-normal distribution was confirmed. Differences in the outcomes between implants placed with CAIS and Freehand were analyzed with the Mann–Whitney *U* test for comparisons involving two independent groups, while the Chi-Square test was applied for analyses of the relationship between categorical variables. p value < 0.05 was considered as statistically significant.

3 | Results

3.1 | General Demographics of Patients and Implant Characteristics

Twenty-seven patients with 30 implants were enrolled in the study, with an average follow-up period of 4.06 years ± 1.7 years (range: 2–6 years) (Table 1). The mean patients' age was 62.4 years (range 23–75 years). Most patients were female (70.4%). All patients had attended annual follow-up examinations after the implant loading. None of the patients was a current smoker. Eleven patients were systemically healthy, while 16 reported well-controlled systemic conditions (Table 1). None of the patients were currently diagnosed or actively treated for Periodontitis, although history of periodontal disease was not recorded.

Characteristics of all 30 implants are presented in Table 2. Most of the patients received implants in replacement of the maxillary central incisor (53.3%). Most common fixture length was 10 mm (78.5%), and the diameter was 4.1 mm (59.3%). Straumann bone level was mostly utilized (70.4%), followed by Straumann bone level taper (29.6%), restored mainly by a screw-retained prosthesis (81.5%).

3.2 | PES Assessment

Overall mean PES was 10.9 ± 1.97 (range 6–14), with a mean of 11.8 ± 1.43 for the CAIS and 10.15 ± 2.32 for Freehand, respectively (Table 3). Table 4 presents the comparison of outcomes with CAIS and Freehand. There was a significant difference in the distribution of the PES in the three categories (poor, acceptable, perfect) between CAIS and Freehand ($p = 0.013$, Mann–Whitney *U* test). The highest achievable score of 14 was assigned 4 times in the CAIS group (10.0%) but to none of the implants in the Freehand group. A score of 13 was assigned 12 times in the CAIS group (30%) and 4 times in the Freehand group (20.0%). Furthermore, 6 was the lowest score assigned in the Freehand group ($n = 1$%, 5.0%), while the lowest in CAIS was 8 ($n = 3$%, 7.5%) (Table 5).

Intra-observer agreement reached an ICC of 0.932 (95% confidence interval: 0.858–0.968), suggesting a high level of consistency across the measurements.

The mean PES values of the thin and thick biotypes were 8.83 (range 6–12, SD ± 1.94) and 11.91 (range 7–14, SD ± 1.50), respectively. No significant difference between thick and thin GB was found in this study ($p = 0.129$, Mann–Whitney *U* test).

3.3 | Marginal Bone Level

The mean MBL was 0.29 mm (±0.56) in CAIS, (d-CAIS: 0.27 ± 0.56 mm, s-CAIS: 0.31 ± 0.5 mm) and 0.74 mm (±0.71) in the freehand group. There was a statistically significant

TABLE 1 | Demographic characteristics of patients.

	Dynamic	Static	Freehand	Total	*p*
Patients					
Patients	9	9	9	27	
Implants	10	10	10	30	
Gender					
Male	2	3	3	8 (29.6%)	0.837
Female	7	6	6	19 (70.4%)	
Age (years)					
Range	23–71	58–73	54–75	23–75	0.109
Mean (SD)	51.6 (18.1)	68.2 (6.0)	67.4 (8.7)	62.4 (10.93)	
Follow-up Period (Years)					
Range	2–6	2–6	2–8	2–8	0.316
Mean	4.0 (±1.41)	4.2 (±1.61)	4.0 (±2.1)	4.06 (±1.7)	
Systemic Conditions					
None	6	4	1	11 (32.4%)	0.360
Hypertension	2	1	3	6 (17.6%)	
High Cholesterol	1	1	1	3 (8.8%)	
Osteoporosis	0	1	0	1 (2.9%)	
Heart Disease	0	2	0	2 (5.9%)	
Diabetes	0	0	4	4 (11.8%)	
Smoking Status					
Non/Former Smoker	9	9	9	27 (100.0%)	1.000
Current Smoker	0	0	0	0 (0.0%)	

difference between CAIS and freehand ($p = 0.001$, Mann–Whitney *U* test) but no statistical difference between dynamic and static CAIS subgroups ($p = 0.917$, Mann–Whitney *U* test).

3.4 | Prevalence of Peri-Implant Disease

There was no significant difference in the frequency of bleeding on probing among the six probed sites at the implant level between the groups (Table 6). When mucositis was defined as ≥2 spots of BoP, there was no significant difference in prevalence between the groups ($p = 0.144$, Chi-Square test). There was no significant difference in the probing depths, with the mean PD for all implants being 4.0 ± 1.36 mm, for implants placed with CAIS 3.98 ± 1.39 mm and freehand 4.06 ± 1.3 mm, respectively. No implants were diagnosed with peri-implantitis as per the case definition used.

3.5 | Patient Reported Outcomes

Patients in the CAIS group presented with higher satisfaction from the esthetics (4.65/5 vs. 4 /5), which showed statistical significance ($p = 0.002$, Mann–Whitney *U* test) (Table 7).

4 | Discussion

The present cross-sectional study compared clinical outcomes and PROMs from patients who received single implants in the esthetic zone with CAIS and freehand surgery. The results of this study revealed overall acceptable esthetic outcomes for both CAIS and freehand placement; however, CAIS showed a statistically significant advantage at least as measured by PES. Furthermore, implants placed with CAIS presented with higher MBLs, but no difference was found in any clinical parametres, such as bleeding on probing and probing depth, including the diagnosis of mucositis, peri-implantitis, and the PROs.

The main findings with regard to PES appear in agreement with a previous study by Furhauser et al. [13]. Likewise, the influence of the mucosa biotype on PES/WES scores is not surprising [23]. Nevertheless, increased accuracy, as achieved by means of CAIS, led to superior esthetic outcomes regardless of the biotype.

Furthermore, this study showed MBL to be significantly higher when CAIS was used, as compared to freehand implant placement. This result is well aligned with previous investigations, where Tallarico et al. 2019 showed implants placed with CAIS

TABLE 2 | Characteristics of implants.

Characteristic	Dynamic	Static	Freehand	*N* (%)	*p*
	10	10	10	Total: 30	
Implant site					
1st Premolar	5	1	2	8 (26.6%)	0.081
Canine	0	0	2	2 (6.6%)	
Lateral incisor	1	3	0	4 (13.3%)	
Central incisor	4	6	6	16 (53.3%)	
Implant fixture length					
8 mm	1	0	0	1 (3.6%)	0.609
10 mm	8	8	8	21 (78.5%)	
12 mm	1	1	2	3 (14.3%)	
14 mm	0	1	0	1 (3.6%)	
Implant fixture diameter					
3.3 mm	6	4	1	11 (40.7%)	0.065
4.1 mm	4	6	9	16 (59.3%)	
Implant fixture type					
BL	3	2	3	19 (70.4%)	0.843
BLT	7	8	7	8 (29.6%)	
Implant prosthesis					
Single	10	9	10	26 (96.3%)	0.355
Cantilever	0	1	0	2 (3.7%)	
Implant prosthesis type					
Screw retained	9	9	8	22 (81.5%)	0.749
Cement retained	1	1	2	5 (18.5%)	

Abbreviations: BL, bone level; BLT, bone level taper.

TABLE 3 | Mean and standard deviation of PES for the implants placed with CAIS (s-CAIS, d-CAIS and total) versus the ones with Freehand.

Group		Mean PES	Std. Deviation	*p*
CAIS	d-CAIS	11.2	1.93	0.076
	s- CAIS	12.5	0.94	
	Total	11.85	1.43	0.013
Freehand—Conventional		10.15	2.32	

to have significantly less marginal bone loss than those placed with freehand in a 5-year period post-loading [24]. This result might also be not surprising, as the positioning of the implant might affect the MBLs both in the short and long terms. In the first case, marginal bone loss might occur in the first few months after placement as part of bone remodeling [25], the extent of which is shown to be affected by implant position (depth, angle of placement, bucco/palatal position, proximity to neighboring teeth etc) [26], as well as the contour [27] and height [28] of restorative components. Thus, it is reasonable to anticipate that the accuracy in the position of the implant could influence the extent of early marginal bone remodeling both directlyand indirectly due to the choice of prosthetic components [29]. In the longer term, marginal bone loss might occur as a result of peri-implantitis, the risk for which can increase by compromised contour and design of the prosthetic components [8], as well as by reduced overall accessibility of the prosthesis to oral hygiene [30]. Consequently, increased accuracy in implant placement can help minimize the early marginal bone remodeling and reduce long-term risks for peri-implantitis, when a digital comprehensive treatment plan is utilized including the design of the proper prosthesis.

Despite its influence in PES and MBL, increased accuracy did not seem to translate into any different outcomes with regard to peri-implant mucosa inflammation and the related signs. Although the mean probing depths in this study appear somewhat higher than what is reported in general [21], this might not be surprising considering that in the esthetic zone a deeper peri-implant

TABLE 4 | Distribution of PES scores in groups as suggested by Altay et al. 2019 [14].

	CAIS					
	d-CAIS		s-CAIS		Freehand	
	N (patient)	%	*N* (patient)	%	*N* (patient)	%
Poor (0–7)	0	0.0%	0	0.0	3	15.0%
Acceptable (8–11)	10	50.0%	3	15.0%	8	40.0%
Almost Perfect (12, 13)	9	45.0%	14	70.0%	9	45.0%
Perfect (14)	1	5.0%	3	15.0%	0	0.0%

sulcus is inevitable if a natural emergence through the scalloped mucosa is desired, simulating peri-implant papilla [31]. No implant was found affected by peri-implantitis. This might be attributed to the duration of the observation period being around 4 years on average, as well as the case definition provided for epidemiological studies, which might allow for high specificity at the expense of sensitivity and early detection. Likewise, the case definition of mucositis remains at present debatable and open to interpretation, at least with regard to consistent use in epidemiological studies. The 2017 World Workshop (Berglundh et al. [21]) defined mucositis by the presence of bleeding and/or pus on gentle probing, with or without increased probing depth compared to previous exams, and no bone loss beyond initial remodeling changes [21]. The bleeding on probing was in addition characterized as "profuse" (line or drop, not "dot", Renvert et al. [21]), in order to distinguish inflammation from potential traumatic bleeding, especially when dichotomous scoring is used [32]. Such a case definition however would require a "qualitative" index for bleeding on probing, with a dichotomous index being largely unable to distinguish between the different extents of bleeding in conjunction to other related signs. Later case definitions appeared to focus on dichotomous bleeding on probing in isolation of other signs and qualitative features, such as this proposed by Herrera et al. 2023, where mucositis is defined as probing resulting in two or more bleeding "dots" after probing six sites around an implant [33]. Nevertheless, the occurrence of bleeding when probing even with consistent force is influenced by many factors [34] such as the operator and the probing force [35], the morphology and characteristics of the tissue [36], and the contour of the prosthesis [7]. There is a high likelihood of false positives, especially when using dichotomous scoring of bleeding not combined with any other clinical signs. Common sense directs that if one bleeding "dot" can be attributed to traumatic probing, then a second one should be at least as likely in the same implant under the same conditions, while two traumatic "dots" do not equal one inflammatory. Thus, the authors have chosen to report the frequency of bleeding sites per implant from 0/6 to 6/6, as is a common practice, while also analyzing the data for one of the proposed case definitions. In the future, case definitions of mucositis based on qualitative features of bleeding on probing in combination with other signs of inflammation [34] might offer a better diagnostic potential to epidemiological studies.

The study did not find any difference in PES and other outcomes between implants placed with static and dynamic CAIS. Given the fact that the majority of clinical trials show no difference in the level of accuracy achieved with static and dynamic CAIS, and as higher accuracy is associated with higher PES, the study would need an unknown but certainly much larger sample to investigate any differences between static and dynamic CAIS. Thus, the secondary objective and investigation of differences between static and dynamic CAIS can only be seen as an "exploratory" attempt.

Patient satisfaction was evaluated using a questionnaire that employed Visual Analog Scale (VAS) 5-point Likert scale and dichotomous measurements. The questionnaire was designed to confirm the subjective perceived characteristics of implant therapy. Patients completing the questionnaire showed a strong positive perception of their treatment. They gave a maximum score of 5 on functional and comfort aspects while rating esthetics at 4 or higher. However, these patient-reported views did not always appear in line with the clinical evaluation using the PES index. One patient with a poor esthetic outcome (PES = 6) expressed esthetic satisfaction as 4/5, while one with PES of 12 expressed the lowest satisfaction with esthetics as 3/5. Such discrepancies have been observed in past studies as well, with Angkaew et al. (2016) reporting similar findings in a study involving 20 single-tooth implants. They observed no correlation between the PES/WES score and VAS scores [23]. Patients' expectations from the implant therapy have been shown to interfere with the expression of satisfaction with the outcomes, which could be particularly pronounced in the case of esthetics [6]. With regards to chewing function however, all patients expressed the highest level of satisfaction. This may be the result related not only to the absence of complications but also to the anterior implants contributing more to patients' perception of esthetics and less in terms of function.

Surgeon's experience is one of the factors that can influence the optimal position in implant placement [37], while implants placed by multiple surgeons might influence the outcomes of clinical trials. Although the implant position was determined by a multidisciplinary team during digital treatment planning, all of the implants in this study were placed by a single experienced surgeon with over 6 years of experience in the use of static and dynamic CAIS.

The result of this study should be seen in the light of the methodological limitations. The study used a convenience sampling and a relatively small sample of 30 implants. The sample size, although adequate to serve the primary outcomes it was calculated for, was inadequate to detect any potential differences between outcomes

TABLE 5 | Pink Esthetic Scores.

Pink Esthetic Score			Assessment 1		Assessment 2		Total	
			No.	%	No.	%	No.	%
CAIS	d-CAIS	8	2	10.0	1	5.0	3	7.5
		9	1	5.0	1	5.0	2	5.0
		10	0	0.0	1	5.0	1	2.5
		11	2	10.0	2	10.0	4	10.0
		12	2	10.0	1	5.0	3	7.5
		13	2	10.0	4	20.0	6	15.0
		14	1	5.0	0	0.0	1	2.5
		Subtotal	10	50%	10	50%	20	50%
	s-CAIS	11	2	10.0	1	10.0	3	7.5
		12	3	15.0	5	50.0	8	20.0
		13	3	15.0	3	30.0	6	15.0
		14	2	10.0	1	10.0	3	7.5
		Subtotal	10	50%	10	50%	20	50%
	Total		20	100%	20	100%	40	100%
Freehand		6	1	10.0	0	0.0	1	5.0
		7	1	10.0	1	10.0	2	10.0
		8	0	0.0	2	20.0	2	10.0
		9	3	30.0	2	20.0	5	25.0
		10	1	10.0	0	0.0	1	5.0
		12	2	20.0	3	30.0	5	25.0
		13	2	20.0	2	20.0	4	20.0
		Total	10	100.0	10	100.0	20	100.0

TABLE 6 | Number of sites (out of total six) per implant positive for bleeding on probing.

Bleeding on Probing	CAIS					
	Dynamic—CAIS		Static—CAIS		Freehand	
	n	%	*n*	%	*n*	%
0/6	0	40	2	30	1	10
1/6	4		1		0	
p			0.155			
2/6	1	60	1	70	2	90
3/6	5		2		3	
4/6	0		4		1	
5/6	0		0		0	
6/6	0		0		3	
p			0.142			

TABLE 7 | Patients reported outcomes on function, comfort, and esthetics as reported in a five-step Likert scale.

	CAIS			
	Dynamic—CAIS	Static—CAIS	Freehand	*p*
Function	5	5	5	1.000
Comfort	5	5	5	1.000
Esthetics	4.7	4.6	4.0	0.002

of static and dynamic CAIS. Thus, the investigation was only exploratory with regard to the secondary objective. Furthermore, the observation period extends to on average 4 years and can be well described as medium term, while only few cases exceeded this margin and reached a long-term follow-up. This might be sufficient to observe the impact on esthetic outcomes and early bone remodeling, but might be relatively short for outcomes such as peri-implantitis, which is a multifactorial disease and likely to be affected by many factors not assessed in this study, such as prosthesis design [4]. The periodontal history of the patients was not recorded, and no detailed periodontal charting was conducted. Furthermore, although all patients received the implants in the Department of Oral and Maxillofacial Surgery, surgeries were conducted by both experienced specialists as well as residents under supervision. Thus, the competence of the operator was not standardized. Finally, the accuracy of implant placement is only meaningful as part of an appropriate treatment plan and prosthesis design. In this study, although all implants were placed by one surgeon, the treatment plan and prosthesis design, as well as restorative procedures, were conducted by multiple prosthodontists, and no attempt was made to account for possible differences in the prosthesis design. Nevertheless, given the scarcity of studies assessing clinical outcomes of CAIS, the study can still offer valuable insights into the use of such technologies. In the future, longer observation periods combined with larger samples followed prospectively could confirm and further investigate the results of such epidemiological studies.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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