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A prospective clinical study of immediate implant placement in the maxillary esthetic zone

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ABSTRACT

Purpose: Immediate implant placement (IIP) offers several advantages, including minimizing hard and soft tissue deformation, reducing implant time and cost, and rapidly restoring tooth function. However, IIP is technically challenging due to the need to secure initial stability and limit functional loading during healing. Therefore, this study aimed to evaluate the clinical outcomes of a bone-level implant featuring a dual thread design—an upper U-shaped thread and a lower V-shaped thread—with an 11° internal hexagonal connection in IIP within the maxillary esthetic zone.

Methods: This study included 20 patients. Implants were inserted immediately after tooth extraction. Soft tissue changes were evaluated before tooth extraction (V0), after IIP (V1), at prosthesis delivery (V5), at a 3-month follow-up after prosthesis delivery (V6), and at a 1-year follow-up (V8). Bone dimensional changes were assessed at V1 and V8 using cone beam computed tomography, and the marginal bone level (MBL) was evaluated at V6 and V8 using 2-dimensional.

Results: Of the 20 patients, 3 dropped out due to osseointegration failure during the follow-up period. Although the horizontal dimensions of the soft and hard tissues decreased slightly, the gingival margin and MBL remained well maintained throughout the follow-up.

Conclusions: Within this limited dataset, the lower V-shaped thread enabled favorable initial stability in IIP, and the esthetic outcomes were positive—with minimal gingival recession and marginal bone loss. Long-term follow-up is required to fully assess the impact of thread design and connection on esthetics.

Trial Registration: Clinical Research Information Service Identifier: KCT0008231

Keywords: Dental implants; Esthetics; Osseointegration

INTRODUCTION

Immediate implant placement (IIP) offers several advantages: it minimizes the deformation of both hard and soft tissues, facilitates accurate implant positioning for the final restoration, reduces treatment time and cost, and rapidly restores tooth function [1]. The survival rates for immediate and delayed implantations have been reported as 94.6% and 98.3%, respectively [2]. Other studies have also shown high implant survival rates over 1–5 years of

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No potential conflict of interest relevant to this article was reported.

Author Contributions
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follow-up [3-5]. In addition, IIP in the maxillary esthetic zone has demonstrated favorable outcomes for both hard and soft tissues [3,6,7].

Despite these benefits, IIP remains technically challenging due to the need to achieve initial stability and restrict functional loading during healing [8]. Primary stability is largely attained by anchoring the fixture in the apical pristine bone [9]. Therefore, several studies have highlighted the importance of thread design in enhancing bone-to-implant surface contact, which can improve initial stability [10]. Given the esthetic importance of the maxillary anterior region, careful attention to these factors during IIP is essential.

Many implant fixture design features—including thread depth, width, pitch, and screw connection contour—affect biomechanical performance after placement [8,10]. The IU implant (**Figure 1**; Warantec Co., Ltd., Seongnam, Korea) used in this study is a bone-level internal implant with several distinctive characteristics. It features a sandblasted, large grit, acid-etched (SLA) surface and employs 2 types of threads: an upper U-shaped thread and a lower V-shaped thread (**Figure 1A**), along with an 11° internal hexagonal connection (**Figure 1B**).

According to the manufacturer, the IU implant reduces cortical bone resorption by positioning the stress point 3.0 mm below the bone level through a combined straight and tapered design (http://www.warantec.co.kr/main.jsp). In addition, the upper U-shaped thread facilitates easy fixation and reduces maximum von Mises stress in the cortical bone, while the lower V-shaped thread—with its narrow width—increases fixation force and simplifies implant installation. The SLA surface enhances bone-to-implant contact and stimulates osseointegration by promoting platelet adhesion and osteoblast migration and differentiation [11,12].

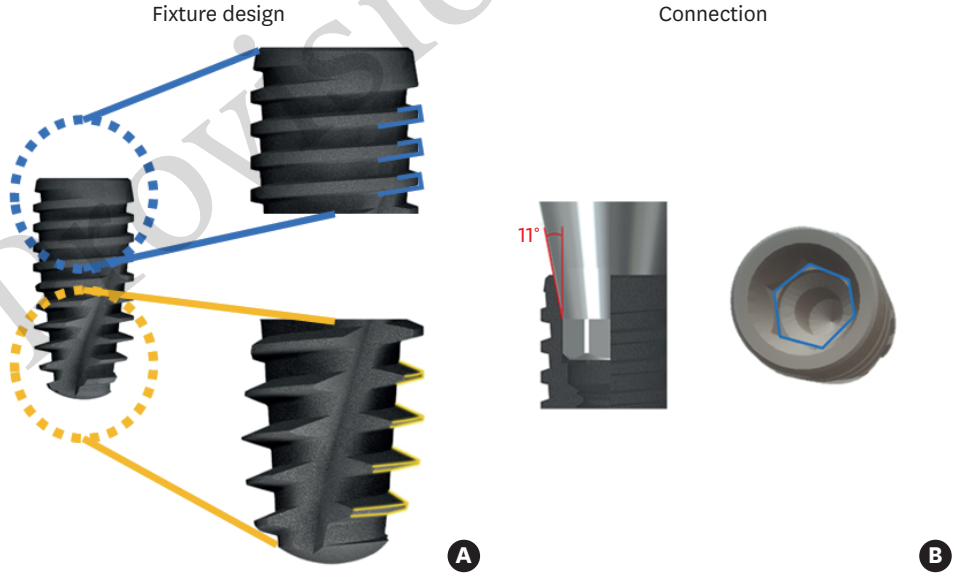

Figure 1. The characteristics of the IU implant. (A) Fixture design. IU implants feature 2 types of threads: an upper U-shaped thread that allows for easy fixation and a lower V-shaped thread that enhances fixation force and simplifies installation. The implant incorporates a mixed design of straight and tapered geometries to position the stress point 3.0 mm below the bone level, thereby reducing cortical bone resorption. (B) Connection. The IU implant utilizes an 11° internal hexagonal connection, providing a stable and secure interface between the implant and the abutment.

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An 11° internal hexagonal connection effectively minimizes and distributes stress on the cortical bone [13], thereby preventing early bone resorption [14]. Platform switching, which occurs when an abutment with a smaller diameter than the implant platform is used, increases the volume of soft tissue around the implant platform and improves esthetic outcomes [15]. Moreover, platform switching can help prevent crestal bone loss, a key factor for long-term implant success and stability [16].

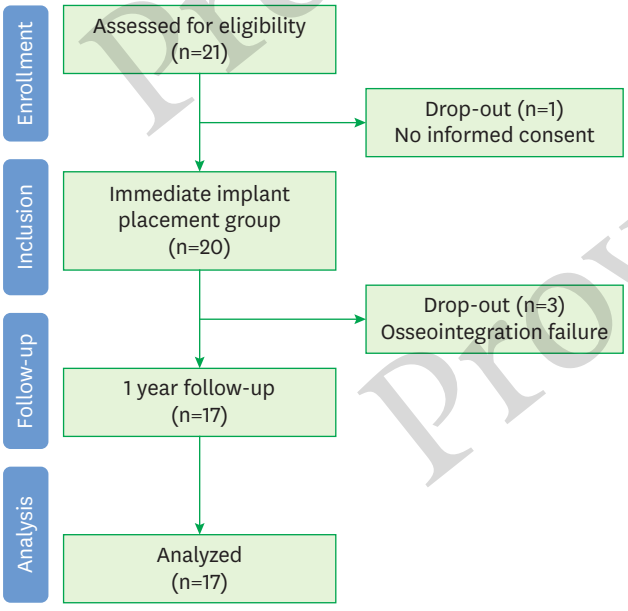
Although the IU implant has demonstrated promising theoretical and experimental results, its clinical outcomes may differ. Therefore, further follow-up studies are required to validate the effectiveness and success of these newly developed implants. The primary objective of this study was to evaluate the clinical outcomes—both soft and hard tissue aspects—of IU implants used in IIP within the maxillary esthetic zone.

MATERIALS AND METHODS

Study design

This study was conducted at Seoul National University Dental Hospital, Korea, between November 2021 and June 2024. The CONSORT flowchart illustrating the study design is shown in **Figure 2A**.

Study flow chart



A

Study procedure

Visit	Days	Treatments	Measurements
V0	-	Patient registration	· Intraoral (IO) scan · Impression
V1	0	Tooth extraction and immediate implant placement	· IO scan · ISQ value · CBCT · IO radiograph
V2	10	Stich out	· IO scan · AE
V3	40	Recall check	· IO scan · ISQ value
V4	70	Recall check	· IO scan · ISQ value
V5	90	Implant prosthesis delivery	· IO scan · IO radiograph
V6	180	Recall check	· IO scan
V7	270	Recall check	· IO scan
V8	450	Recall check	· IO scan · CBCT · IO radiograph

B

Figure 2. Study flow chart and procedures. (A) Study flow chart. A total of 21 patients were initially enrolled; however, 1 patient did not consent and was dropped. Twenty patients underwent immediate implant placement, and 3 experienced osseointegration failure, leaving 17 patients for follow-up and analysis. (B) Study procedure. Following patient registration (V0), IIP was performed after tooth extraction (V1). The healing process was evaluated at 10 days (V2), 40 days (V3), and 70 days (V4) post-IIP. The implant prosthesis was delivered at 90 days (V5). Recall checks were conducted at 180 days (V6) and 270 days (V7) after prosthesis delivery, with a final follow-up at 450 days (V8).
IO: intraoral, ISQ: implant stability quotient, CBCT: cone beam computed tomography, AE: adverse events, IIP: immediate implant placement.

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Ethical consideration

This study adhered to the principles of the Helsinki Declaration of 1975, as revised in 2013. It was approved by the Institutional Review Board (IRB) of Seoul National University Dental Hospital (IRB No. CDE21010) and registered with the Korean Clinical Research Information Service (KCT0008231). The study was conducted according to the principles in the Declaration of Helsinki on human medical experimentation. All participants received detailed information regarding the study's objectives and procedures, provided written informed consent voluntarily, and were assured that opting out would not lead to any adverse consequences.

Study population

The sample size was determined by assessing the clinical effectiveness of the test device via the lower limit of the 95% 1-sided confidence interval (CI) for changes in alveolar bone volume before and after device application, with a type 1 error of 5% and a test power of 70% (type 2 error of 30%). Based on these parameters, 20 participants were required. Patients aged 19–75 years with a single anterior tooth requiring extraction and implant placement were recruited. The extraction socket and bone wall were required to have at least 2 intact walls, and patients needed to have a minimum of 20 remaining teeth (including prosthetic teeth). Additionally, the plaque and bleeding indices in the anterior jaw had to be less than 20% at the time of probing. Exclusion criteria were: 1) patients with systemic diseases such as unstable angina, myocardial infarction, or transient ischemic attack within the last 6 months; coronary artery disease; severe cerebrovascular disorders (e.g., stroke, cerebral infarction, or cerebral hemorrhage) within the last 6 months; clinically significant renal or hepatic dysfunction; or uncontrolled diabetes; 2) patients without posterior occlusion; and 3) patients who smoked. This study involved a single experimental group—"tooth extraction and IIP"—and, therefore, randomization and blinding were not utilized. The study was designed as a prospective investigation.

Study procedure

This study was performed in accordance with the study protocol (**Figures 2B** and **3**). Following patient registration (V0), IIP was performed (V1). After tooth extraction, the socket was thoroughly cleaned and irrigated to remove granulation tissue. An IU implant was then immediately placed in an optimal 3-dimensional (3D) orientation to achieve satisfactory primary stability. If the implant's initial stability was adequate (implant stability quotient [ISQ] >50), a 1-stage surgery was performed. If the initial stability was insufficient (ISQ ≤50) or if guided bone regeneration was indicated, a 2-stage surgery was chosen. Any labial defect was repaired using bovine bone mineral (Cerabone®, botiss biomaterials GmbH, Zossen, Germany), and the space between the implant and the socket wall was filled with the bone substitute. An absorbable collagen membrane (Jason® membrane, botiss biomaterials GmbH) was placed over the grafted area. In cases where primary closure was not initially achieved—resulting in partial exposure of the collagen membrane or necessitating passive soft tissue closure—primary closure was subsequently performed. After 10 days post-IIP, stitches were removed (V2), and the healing process was evaluated at 40 days (V3) and 70 days (V4). The implant prosthesis was delivered 90 days after IIP (V5), with recall checks at 180 days (V6), 270 days (V7), and a final follow-up at 450 days (V8). All surgeries and restorations were performed by 2 periodontists (S.K. and Y.D.C.) and 1 prosthodontist (Y.Y.). 3D scanning, cone beam computed tomography (CBCT), 2D radiography, and ISQ measurements were performed at scheduled time points for combined analysis.

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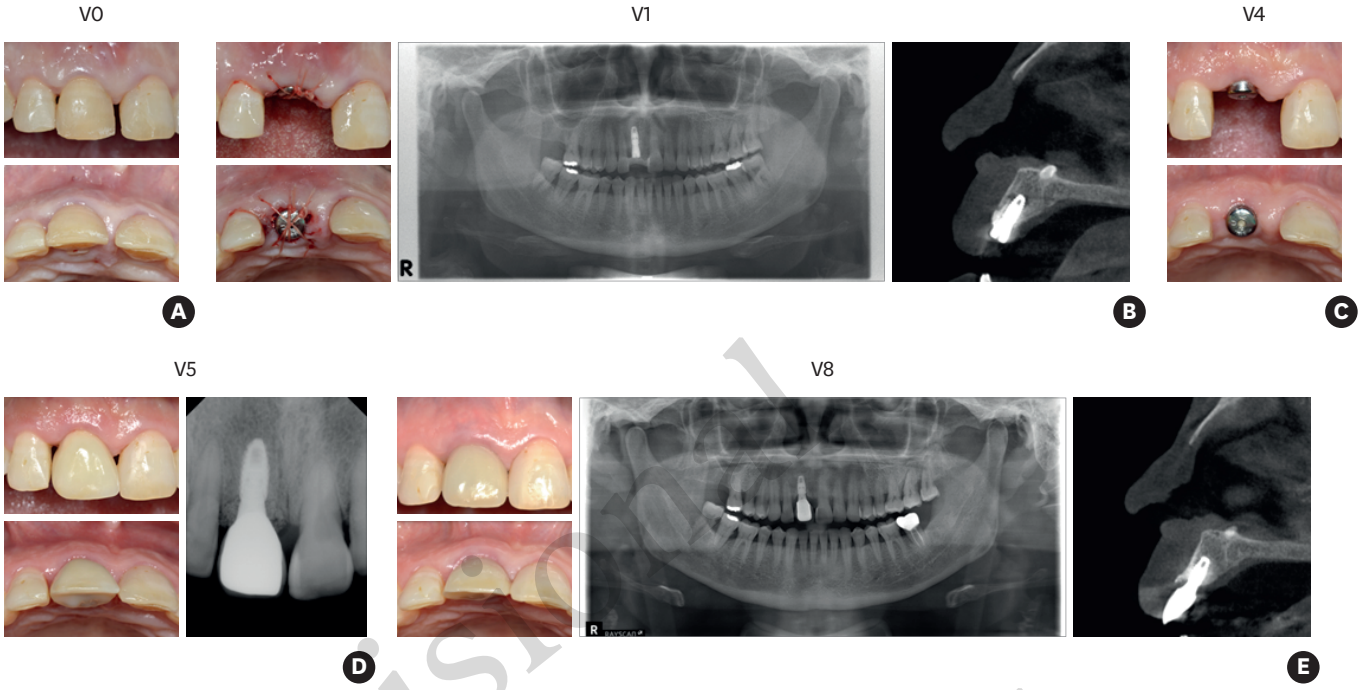

Figure 3. Clinical procedures. (A) Pre-extraction (V0). (B) Immediate implant placement (V1). (C) Recall check before implant prosthesis (V4). (D) Implant prosthesis delivery (V5). (E) Final recall check (V8).

Implant success and survival

Success and survival criteria were based on the guidelines of the International Congress of Oral Implantologists Pisa Consensus Conference [17]. Implant success, assessed under functional load, required the absence of pain or tenderness during function, no mobility, less than 2 mm of radiographic bone loss from the time of initial surgery, and no history of exudate. Implant survival was defined as the presence of the implant in the mouth at the time of examination following functional loading.

3D digital linear analysis

Changes in soft tissue were assessed using an optical scanner (Medit, Seoul, Korea), and STL files were analyzed with digital imaging software (Medit Design, Seoul, Korea). The files were superimposed at various time points (V0, V1, V5, and V8) using the gingival margins of the adjacent teeth in the mesial and distal regions as reference points [18]. The region of interest was divided into 2 equal parts along a selected bucco-oral cross-section (**Figure 4A**). Prior to tooth extraction (**Figure 4A**), the gingival margins on the buccal and palatal sides were used as a reference line, and the horizontal alveolar ridge width (HW) was measured at 1 mm (HW-1), 3 mm (HW-3), and 5 mm (HW-5) below this line. For midfacial recession, a straight line passing through the most apical point of the gingiva of the tooth adjacent to the implant served as the reference line, and the perpendicular distance from the most apical point of the implant crown to this line was measured at V0, V1, V6, and V8 [18] (**Figure 4B**).

CBCT radiographic analysis

To evaluate changes in alveolar ridge dimensions over time, CBCT was performed at V1 and V8. The images were superimposed and analyzed using specialized software (OnDemand; Cybermed, Seoul, Korea) [19]. Superimposition was based on 3 or more anatomical landmarks in cranial areas unaffected by the healing process, and an apical reference point

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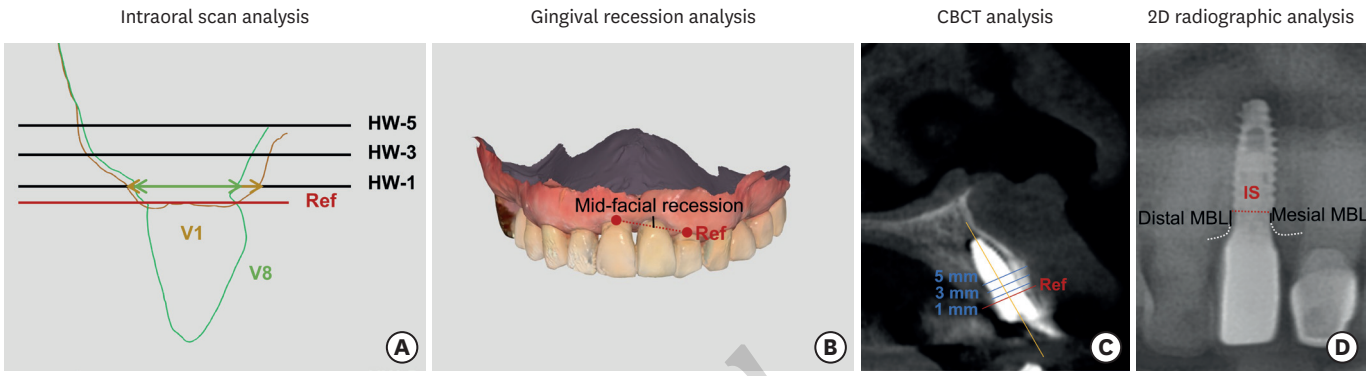

Figure 4. Methods for evaluating intraoral scans and radiographs. (A) Intraoral scan analysis. STL files were superimposed at different time points using adjacent teeth as reference points. The HW was measured at 1 (HW-1), 3 (HW-3), and 5 (HW-5) mm below the reference line. (B) Gingival recession analysis. Midfacial gingival recession was measured as the perpendicular distance from the most apical point of the implant crown to a reference line drawn through the gingiva of the adjacent tooth. (C) CBCT analysis. Two CBCT images were superimposed using specialized software. Buccal bone thickness and buccolingual width of the alveolar bone around the implant were measured using a reference line (red; Ref) at the implant shoulder level, with additional lines (blue) drawn 1, 3, and 5 mm below it. The alveolar bone ridge width was measured along these lines, and buccal bone thickness was calculated by subtracting the ridge width from the distance between the inner buccal bone surface and the outer palatal bone wall. (D) 2D plane radiographic analysis. MBL changes were evaluated by comparing panoramic radiographs taken immediately after implant prosthesis delivery (V6) and at 450 days post-placement (V8). The mesial and distal distances (black line) between the IS (red dotted line) and the first bone-to-implant contact (white dotted line) were measured. MBL changes were calibrated using the known implant lengths.
HW: horizontal alveolar ridge width, CBCT: cone beam computed tomography, 2D: 2-dimensional, MBL: marginal bone level, IS: implant shoulder.

was established at the implant apex. Two reference lines were defined: a vertical line passing through the center of the implant and the apical reference point, and a horizontal line at the implant shoulder, perpendicular to the vertical line. Buccal bone thickness and buccolingual bone width were measured along the horizontal reference line at the implant shoulder, with additional measurements at 1 mm, 3 mm, and 5 mm below it [20]. The ridge width was measured along these lines (**Figure 4C**), and buccal bone thickness was determined by subtracting the alveolar bone ridge width from the distance between the inner surface of the buccal bone and the outer surface of the palatal bone wall.

2D plane radiographic analysis

Marginal bone-level changes were evaluated by comparing radiographs taken at V6 and V8. Marginal bone height was measured as the distance from the reference point on the implant shoulder to the first bone-to-implant contact at both the mesial and distal aspects (**Figure 4D**). These measurements were calibrated using the known implant length [21].

Stability evaluation

Implant stability was assessed at V2, V3, and V4 using a resonance frequency analyzer (Osstell®, Osstell AB, Gothenburg, Sweden) to quantify the ISQ.

Safety evaluation

Adverse events (AEs) were systematically monitored using questionnaires and self-reports. Information regarding onset, duration, severity, and any actions taken was recorded, and events were categorized as either AEs or severe AEs.

Statistical analysis

Data were expressed as mean values, standard deviations, and percentages. Statistical analyses were performed using IBM SPSS Statistics 21 (SPSS Inc., Chicago, IL, USA). Implant survival and success rates were calculated as percentages. Assuming a normal distribution for the 3D horizontal volume changes and radiographic measurements, paired-sample *t*-tests with a 95% CI were used to compare measurements at multiple time points [20].

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RESULTS

Demographic data of the study population

A total of 20 patients underwent IIP. The demographic details of the participants are presented in **Table 1**. Early osseointegration failure occurred in 3 patients, leaving 17 patients for the clinical and radiological analyses.

Analyses of the 3D intraoral scan images

Soft tissue changes are detailed in **Table 2**. Compared to pre-extraction measurements, there was a statistically significant reduction in HW-1 at V5 and V8 and in HW-3 at V8. The midfacial gingival changes, presented in **Table 3**, showed no statistically significant differences; however, there was a tendency toward a decreased distance between the zenith of the implant mucosa and the line connecting the gingival zeniths of the adjacent teeth.

Radiographically horizontal ridge changes measured by CBCT

Significant differences were observed in the radiographic buccolingual width and buccal bone thickness at 1 mm, 3 mm, and 5 mm from the reference line between V1 and V8. The largest difference in buccal bone thickness was found at 5 mm from the reference line (0.48 ± 0.49 mm), while the smallest difference was at 3 mm (0.34 ± 0.51 mm) (**Table 4**). Similarly, the greatest change in buccolingual width occurred at 5 mm (0.78 ± 0.82 mm), with a change of 0.63 ± 0.86 mm noted at 3 mm (**Table 4**).

Table 1. Demographic information

Parameters	Immediate implant placement (n=20)	
	Success (n=17)	Failure (n=3)
Age	59.4±12.8	66.7±3.79
Male/female	5/12	1/2
Reason for extraction (bone loss/fracture)	12/5	3/0
Distribution of implant diameter (Φ3.6/Φ4.0 mm)	6/11	1/2
Distribution of implant length (8.5/10/11.5/13 mm)	5/9/0/3	2/0/1/0

Values are presented as mean ± standard deviation.

Table 2. The soft tissue changes recorded from each group at V0, V1, V5, and V8

Measurement site	V0	V1	V5	V8	Changes between V1–V5	Changes between V1–V8
HW-1 (mm)	8.68±1.45	8.93±0.98	7.43±1.33	7.76±1.25		
P value		0.837	0.023[a]	0.019[a]	0.22	0.27
HW-3 (mm)	10.62±1.57	12.12±1.41	10.39±1.33	9.74±1.52		
P value		0.261	0.559	0.034[b]	0.38	0.07
HW-5 (mm)	12.24±1.51	14.69±1.12	11.94±1.04	11.23±1.71		
P value		0.06	0.47	0.17	0.04[c]	0.02[c]

Values are presented as mean ± standard deviation. Data are shown as follows: V0, pre-extraction; V1, immediately after immediate implant placement; V5, 90 days after implant placement; V8, 1 year after delivery of implant prosthesis.
HW: horizontal alveolar ridge width.
[a]Significantly different compared with V0 at the HW-1 level (statistical significance level was 5%, $P < 0.05$).
[b]Significantly different compared with V0 at the HW-3 level (statistical significance level was 5%, $P < 0.05$).
[c]Significantly different when comparing the 2 periods at the same level (statistical significance level was 5%, $P < 0.05$).

Table 3. The mid-facial mucosal changes recorded from each group at V0, V1, V6, and V8

Mid-facial mucosal parameter	V0	V1	V6	V8	Changes between V6–V8
Recession (mm)	1.86±0.65	1.82±1.82	1.25±0.74	1.21±0.62	
P value		0.94	0.02[a]	0.01[b]	0.88

Values are presented as mean ± standard deviation. Data are shown as follows: V0, pre-extraction; V1, immediately after immediate implant placement; V6, 180 days after implant placement; V8, 1 year after delivery of implant prosthesis.
[a]Significantly different compared with V0 at V6 (statistical significance level was 5%, $P < 0.05$).
[b]Significantly different compared with V0 at V8 (statistical significance level was 5%, $P < 0.05$).

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Table 4. Radiographic analysis of horizontal and vertical changes in alveolar ridge dimensions (cone beam computed tomography)

Measurement site and depth	V1	V8	Difference	*P* value
Buccal bone thickness				
1 mm	2.14±1.05	1.71±0.68	−0.43±−0.62	0.01[a]
3 mm	1.98±1.10	1.63±0.80	−0.34±0.51	0.00[a]
5 mm	1.94±1.10	1.47±0.80	−0.48±0.49	0.00[a]
Bucco-lingual width				
1 mm	8.11±1.33	7.34±0.97	−0.76±0.97	0.01[a]
3 mm	8.30±1.57	7.67±1.30	−0.63±0.86	0.01[a]
5 mm	8.90±2.09	8.12±1.87	−0.78±0.82	0.00[a]

Values are presented as mean ± standard deviation. Data are shown as follows: V1, immediately after immediate implant placement; V8, 1 year after delivery of implant prosthesis.
[a]Significantly different at the same level compared to V1 statistical significance level was 5%, $P < 0.05$).

Radiographically vertical ridge alteration measured by 2D radiography

No significant differences in marginal bone levels (MBLs) were observed between V6 and V8 at either the mesial or distal aspects (**Table 5**).

Implant stability outcomes

Implant stability, as measured by ISQ values, increased on both the buccal and palatal sides from V2 to V4. The average ISQ value exceeded 70 at V4, just before implant prosthesis delivery (**Table 6**).

Safety evaluation

No AEs were recorded other than the removal of 3 implants due to early osseointegration failure (**Table 7**).

DISCUSSION

In this study, the implant success rate was 85% due to early osseointegration failures prior to prosthesis delivery, while the survival rate after functional loading was 100% during the

Table 5. Marginal bone level measured by radiography

Measurement site	V6	V8	*P* value
Mesial	−2.13±0.34	−1.56±0.39	0.053
Distal	−1.37±0.50	−1.78±0.40	0.58

Values are presented as mean ± standard deviation. − means that the marginal bone height is higher than the implant shoulder (reference). Data are shown as follows: V6, 180 days after implant placement; V8, 1 year after delivery of implant prosthesis.

Table 6. Assessment of the implant stability using resonance frequency analysis at V2, V3 and V4 days after implant placement

Measurement site	V2	V3	V4
Buccal	60.0±6.4	65.0±10.0	74.0±7.9
Palatal	59.4±6.8	64.9±9.87	76.4±10.9

Values are presented as mean ± standard deviation. Data are shown as follows: V2, 10 days after immediate implant placement; V3, 40 days after implant placement; V4, 70 days after implant placement.

Table 7. Number of AE, SAE, and DD reported across every visit

Adverse event category	Values (n=20)
AE	3
SAE	0
DD	0

AE: adverse events, SAE: serious adverse events, DD: device deficiencies.

follow-up period. This high survival rate aligns with a previous study reporting a 99% survival rate for IU implants over a 6-year period [14].

The causes of implant failure appeared multifactorial, involving systemic health conditions, local anatomical challenges, and peri-implant factors. Early implant failure is often associated with a history of periodontal problems, poor bone quality, or immediate loading [22]—factors that were present in the failure cases observed. One patient, who presented with severe caries and advanced periodontal disease (possibly stage 4 grade B periodontitis) along with a history of osteoporosis managed with intra-articular injections, experienced implant failure within 1 month despite an initial insertion torque of 30 Ncm. In another case, failure occurred 2 months post-placement, likely due to a lateral periapical lesion. A third patient experienced failure 3 months after placement, with the implant site exhibiting a narrow ridge and close proximity to the incisive canal, potentially increasing biomechanical challenges; a lateral periapical lesion also suggested localized infection or peri-implant pathology. These findings highlight the complex interplay of systemic conditions, anatomical constraints, and surgical or biomechanical factors in implant failure, emphasizing the need for thorough preoperative evaluation and risk assessment to minimize early failures.

While previous studies have focused on hard tissue changes, recent concerns have shifted toward esthetic outcomes related to soft tissue changes [3]. In this study, soft tissue dimensions around the implants were evaluated using intraoral scanning. The analysis revealed a statistically significant decrease in HW-1 at V5 and V8 and in HW-3 at V8 compared to the extraction site. Notably, the magnitude of change was smaller than the 1.3 mm reported in another study [23]. A prospective 5-year study of esthetic outcomes in single immediate implants demonstrated high long-term viability and reduced gingival margin loss [24], although midfacial recession and contour worsened after 1 year. Other studies have reported a risk of central facial mucosa recession with IIP [22,25], with an average midfacial recession of 0.29 mm over 2–5 years and advanced recession observed in approximately 13% of patients [3] or 7% showing progression >1 mm after 1 year [6]. In our study, although no significant difference in midfacial gingival changes was detected, there was a trend toward a decreased distance between the zenith of the implant mucosa and the line connecting the gingival zeniths of adjacent teeth. This may be attributable to the harmonious interaction between the soft tissue and the implant's 11° internal hexagonal connection, suggesting that IU implants may contribute to a stable and aesthetically pleasing gingival contour in the esthetic zone.

CBCT analysis revealed significant differences in buccolingual width and buccal bone thickness at 1, 3, and 5 mm from the reference line between V1 and V8. These findings are consistent with a study reporting an average width reduction of 0.5 mm after 6 months of IIP with gap-filling using bovine bone [26]. Various strategies have been used to address the gap between the implant and the buccal bone wall during IIP. A recent review [1] emphasized that filling this gap with slowly resorbing biomaterials is crucial to reduce bone resorption after tooth extraction, and soft tissue augmentation is recommended for patients with a thin gingival biotype. The IU implant's platform-switching design and internal hexagonal connection are intended to minimize alveolar bone loss. Previous reports have shown mesial and distal marginal bone loss of 0.04, −0.07, 0.09, and 0 mm, and 0.05, 0.07, 0.08, and 0 mm at 1, 2, 4, and 6 years, respectively, for IU implants [14]. In our study, although the MBL decreased, it remained above the reference implant shoulder, possibly reflecting the remodeling process of the extraction socket and the tapered design's ability to provide stability by applying pressure to the cortical bone in areas of diminished bone quality [27].

This study has several limitations. First, the relatively short follow-up period limits conclusions regarding the long-term stability and effectiveness of IIP in the maxillary esthetic zone. Ongoing follow-ups and additional clinical data collection are planned to address this limitation. Second, the small sample size reduces statistical power and limits generalizability. Lastly, the absence of a control group precludes direct comparisons with alternative approaches, such as delayed implant placement or other implant systems. Future studies with larger cohorts, longer follow-up periods, and inclusion of matched control groups are necessary to validate these findings and provide more robust evidence for the clinical application of the IU implant system.

An additional limitation is the lack of detailed stratification of clinical outcomes based on the specific morphology of bone defects (e.g., 2-wall, 3-wall, or 4-wall defects) [28]. Although IIP was performed in defects with at least 2 remaining walls, the decision to use bone grafting materials and collagen membranes was based on the surgeon's judgment. Future studies should stratify patients by the number of remaining bone walls to better understand how defect morphology affects the effectiveness of IIP and adjunctive bone grafting procedures. A more comprehensive analysis of these factors could offer greater insight into optimal management strategies for various defect types and their clinical outcomes.

Within the limitations of the study, the findings highlight the clinical potential of the IU implant for IIP in the maxillary esthetic zone. The distinct dual thread design—combining upper U-shaped and lower V-shaped threads—facilitated initial stability, while the 11° internal hexagonal connection effectively minimized marginal bone resorption. Both 3D intraoral scanning and CBCT analyses demonstrated favorable soft and hard tissue outcomes, with minimal gingival recession and stable MBLs over the follow-up period.

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