The Use of a New Safe Angle Concept for Immediate Implant Placement in the Anterior Maxilla: A Cross-Sectional CBCT Study

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Purpose: To introduce a new method for labiopalatal positioning and angulation of immediately placed dental implants in the anterior maxilla with relation to the type of abutment used (straight/angled abutment). ***Materials and Methods:*** CBCT scans from the database of a private practice were searched for patients who received immediate implants in the anterior maxilla. After superimposition of the initial and postoperative scans, the incisor root angle (IRA), incisor implant angle (IIA), and the difference between these angles were measured. An assessment was then made about whether the implant position would be within the safe angle or not. Age, sex, tooth/implant site, and type of prosthetic abutment (straight/angled) were retrieved from the patients' records. ***Results:*** A total of 74 patients with 95 immediate implants altogether were selected for analysis. In regard to the type of abutment, 76 (80%) were straight, and 19 abutments (20%) were angled. Regardless of abutment type, 72 implants (75.8%) were placed within the safe angle, while 23 implants (24.2%) were placed outside it. All 19 implants with angled abutments were placed outside the safe angle. There were statistically significant associations between placement within the safe angle and type of abutment ($P < .001$; OR = 19), IRA ($P < .001$; effect size = 0.904), difference between IIA and IRA ($P < .001$; effect size = 1.209), and sex ($P < .001$; OR = 2.995). There was no statistically significant association between placement within the safe angle and IIA ($P = .757$, effect size = 0.063), site ($P = .200$; effect size = 0.184), or age ($P = .387$; effect size = 0.208). There was a statistically significant association between the type of abutment and the IRA ($P = .001$; effect size = 0.762) as well as the difference between IIA and IRA ($P < .001$; effect size = 1.056). ***Conclusions:*** The safe angle concept can be used as a reliable planning tool to determine the correct implant positioning for immediate implant placement in the anterior maxilla. Applying the safe angle concept will reduce the need for angled abutments for prosthetic correction. *Int J Oral Maxillofac Implants 2024;39:e77–e86. doi: 10.11607/jomi.10578*

Keywords: anterior maxilla, CBCT, immediate implant placement, safe angle concept

Immediate implant placement (IIP) in the anterior maxilla has long been considered a reliable treatment option for replacing nonrestorable teeth.[1] However, despite being a highly accepted clinical approach, IIP in the anterior maxilla has been associated with several esthetic complications, including fenestration of the labial/palatal bone walls, gingival recession, and labiopalatal ridge collapse.[2] Achieving an esthetic restoration after tooth extraction remains a challenge in the presence of a resorbed alveolar ridge,[3] as the final esthetic outcome is highly dependent on preserving facial soft and hard tissue dimensions.[4] Several surgical and prosthetic techniques have been proposed to maintain hard and soft tissue surrounding the implant.[5,6] Kan et al[7] suggested the use of soft tissue grafting at the same time of IIP with a provisional restoration. Alternatively, Degidi et al[8] proposed the "chamber" concept that uses bone graft to fill the socket to the level of the bone crest along with provisional restoration but without soft tissue grafting. On the other hand, Chu et al[9] introduced the "dual zone therapeutic" concept by grafting the whole labial gap to the margin of the soft tissue followed by a provisional restoration.

The ultimate challenge in anterior IIP is the anatomical and morphologic variation of the maxilla, as well as the thin labial plate of bone around maxillary anterior teeth, which was reported to be less than 1 mm in 85% of cases.[10–13] Moreover, the root position in the alveolar

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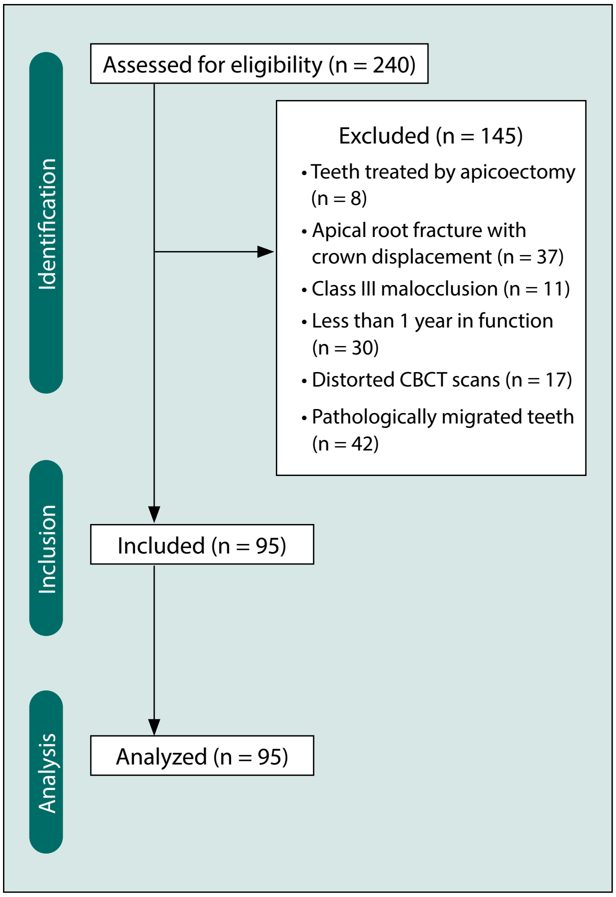

Fig 1 STROBE flow diagram.

envelope is considered to be a crucial factor in determining the implant position and thus the final restorative outcome.[14,15] As the maxillary anterior teeth were shown to have different sagittal inclinations inside the alveolar housing,[15] an ideal IIP position is difficult to achieve. Furthermore, there is variance between the crown and the root long axis angulation of anterior teeth ranging up to 25 degrees.[16] It is also worth noting that the incisal edges of the anterior teeth are more palatally inclined than the labial surface of the crown, thus forming different labial surface angles with the occlusal plane.[17–19]

This complex relationship between the maxillary alveolus, root position, and incisal edge location may lead to a labially inclined implant position.[20,21] Angled abutments are frequently used to correct these unfavorable labial implant inclinations.[22] Unfortunately, however, the abutments' angle correction coronal to the labial crest of bone can cause more soft tissue recession and esthetic failure compared to straight abutments.[23–25] Recently, a subcrestal angle correction implant (SAC) has been proposed to increase the soft tissue gap above the implant platform.[26,27] Despite promising results, choosing the correct 3D positioning of immediate implants in the anterior maxilla remains the pivotal factor for an optimal esthetic outcome.

The purpose of this study was to introduce a new assessment method for the labiopalatal positioning and angulation of immediately placed implants in the anterior maxilla with relation to the type of abutment used (straight/angled abutment).

MATERIALS AND METHODS

This observational cross-sectional study was compliant with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).[28] The study of the "New Safe Angle Concept" was approved by the Research and Ethical Committees, Faculty of Oral and Dental Medicine, Misr International University (no. MIU-IRB-2223-222) and registered at Clinical trials.gov (ID: NCT05436158). After ensuring their data protection, confidentiality, and privacy, the registered patients provided a written informed consent in accordance with the Declaration of Helsinki of 1975 as revised in 2013. It approved the use of their data, clinical pictures, radiographs, and/or CBCT scans for research purposes.

Patient Selection

CBCT scans from the database of a private dental practice (Cairo, Egypt) were searched for patients who received IIP in the anterior maxilla (incisor-canine area). A total of 200 CBCT scans were screened. Only scans of patients with functionally restored implants in place for more than 1 year were included. Scans were excluded if one of the following criteria was applicable:

- Any teeth treated by apicoectomy
- Presence of apical root fracture with crown displacement
- Presence of apical root resorption or pathologically migrated teeth
- Class III malocclusion
- Implants in function less than 1 year
- Presence of multiple adjacent implants
- CBCT scans with severe scattering and/or distorted images

A total of 200 patients and 240 implants were screened. After inclusion and exclusion criteria were applied, 74 patients with a total of 95 implants were included in this study (Fig 1).

All the included cases were performed by the principal investigator, an expert clinician in the implantology field (A.A.). Thorough 3D planning was performed prior to IIP to obtain a prosthetic implant position where the implant long axis was at or palatal to the cingulum of the virtually planned crown on the CBCT. Surgical

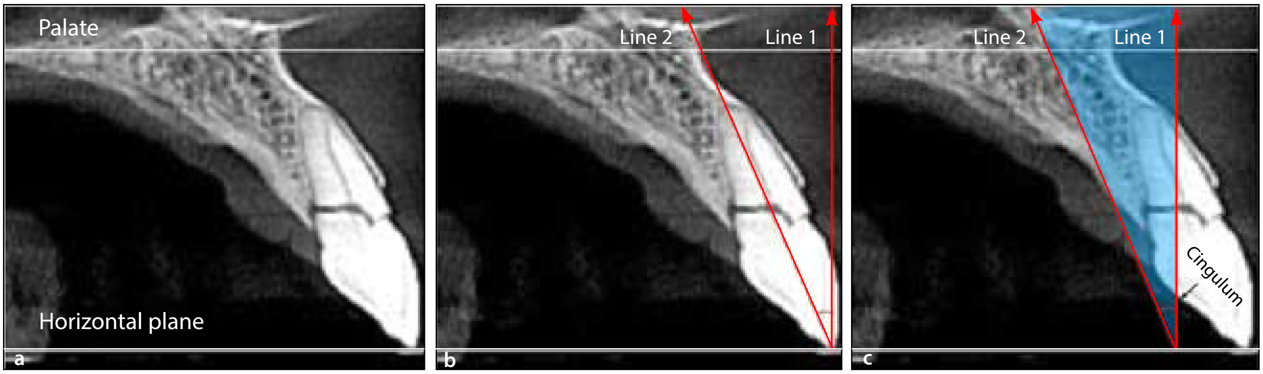

Fig 2 CBCT landmarks for creation of the safe angle. *(a)* Preoperative cross-sectional view of a fractured maxillary central incisor. The palatal plane is oriented to be parallel to the horizontal plane. *(b)* Line 1 is a line perpendicular to the horizontal plane passing through the incisal edge, and line 2 is a line along the long axis of the root. The angle between them forms the incisor root angle (IRA). *(c)* The angular measurement is moved palatally along the horizontal plane reference line until line 1 reaches the cingulum area, forming the safe angle *(shaded area).*

interventions for IIP included flapped or flapless with or without bone grafting (either inside and/or outside the socket).

Demographic Variables

The recorded demographic variables retrieved from the documented patient data included age, sex, tooth/implant site ,and type of prosthetic abutment (straight/angled).

CBCT Analysis

All radiographic records were obtained by small-volume CBCT scans of the maxillary arch (Cranex, Soredex) with a field of vision 6 × 8 cm^2 at peak KVp of 90, 10 mA, exposure time of 6.1 seconds, and a resolution of 0.2 mm (200 µm) voxel size. All data were acquired in a DICOM format and imported to OnDemand3D App software (Cybermed). To perform radiographic measurements and comparisons and to ensure standardization and reproducibility of the CBCT images, superimposition of DICOM file sets for each patient was performed using Fusion module software (OnDemand3D version 1.0.9, Cybermed), which allowed subvoxel accuracy.[29] On the fusion module, both initial and postoperative volumes were superimposed and loaded at the same time. Manual registration was done by approximation of both volumes in three planes (axial, sagittal, and coronal). Automatic registration was then performed by the software, with a slice thickness of 2.5 mm, to average the area of interest without compromising the diagnostic image quality.[30]

Creation of the safe angle

On the initial cross-sectional cut, the palatal plane was oriented to be parallel to the horizontal plane, meeting the incisal edges (Fig 2a). A line perpendicular to the horizontal plane at the incisal edge was placed (line 1), while another line (line 2) was placed along the root long axis to form the incisor root angle (IRA) (Fig 2b). This angular measurement was moved palatally on the horizontal plane reference line until line 1 reached the cingulum area. This angle was named the "safe angle" (Fig 2c).

Assessment of the implant position

In order to assess whether the implant position would be within the safe angle or not, the fused cross-sectional cut was then inverted to the postoperative cut, maintaining the same coordinates of the previously recorded safe angle. Implants positioned between line 1 and line 2 with their long axis palatal to the incisal edge were considered to be within the safe angle (Fig 3), while implants inclined beyond the range of lines 1 and 2 were considered to be outside the safe angle (Fig 4). The incisor implant angle (IIA) was recorded similar to the IRA, where line 2 represented the implant long axis. The difference between IIA and IRA was calculated as follows: IIA – IRA.

Statistical Analysis

Qualitative data were presented as frequencies and percentages. Chi-square test or Fisher's exact test was used to compare qualitative variables. Quantitative data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Age data showed normal (parametric) distribution, while the data on IRA, IIA, and the difference between the two angles showed abnormal (nonparametric) distribution. Quantitative data were presented as means ± SD, medians, and ranges. For parametric data, Student *t* test was used for comparison between two groups. For nonparametric data, Mann-Whitney *U* test was used for comparison between two groups. Binary logistic

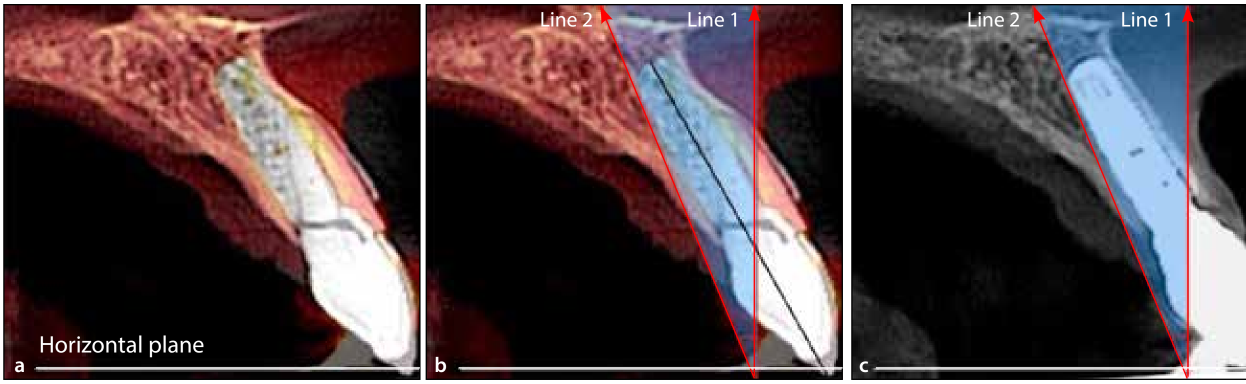

Fig 3 CBCT analysis of an implant lying within the safe angle in a maxillary central incisor. *(a)* Superimposition of the initial and postoperative CBCT scans showing the tooth and the implant shadow. *(b)* Superimposed cut showing the implant within the safe angle (between lines 1 and 2) with a long axis slightly palatal to the incisal edge *(black line)*. *(c)* Postoperative cut showing the implant lying within the safe angle *(shaded area)*.

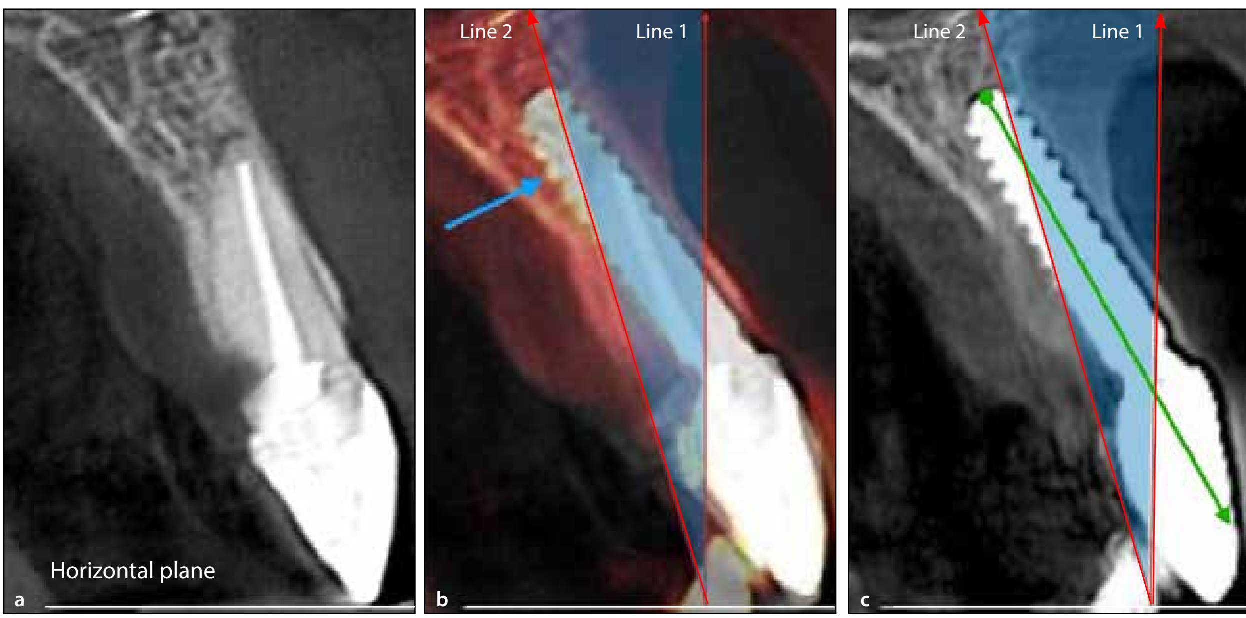

Fig 4 CBCT analysis of an implant lying outside the safe angle. *(a)* Preoperative cross-sectional view of a maxillary central incisor. *(b)* The superimposed cut showing the implant inclined beyond lines 1 and 2 and therefore outside the safe angle *(blue arrow)*. *(c)* Postoperative cut showing the implant position outside the safe angle, with its long axis labial to the incisal edge *(green line)*. Note that an angled abutment was used to correct the labial inclination of the implant.

regression analysis was used to determine significant predictors of lying within the safe angle. Model fit was tested using -2 log likelihood test and pseudo r2 tests. The regression coefficient (β), standard error (SE), odds ratio (OR), and 95% confidence interval (95% CI) were calculated. Discriminant analysis was performed to determine discriminant functions for prediction of lying within the safe angle based on data of sex, age, tooth type, IRA, IIA, as well as the difference between the two angles. The significance level was set at $P \leq .05$. Statistical analysis was performed with IBM SPSS Statistics for Windows (version 23.0, IBM).

RESULTS

Descriptive Statistics

The present study was conducted on 74 patients—42 women (56.8%) and 32 men (43.2%)—ranging in age from 21 to 54 years old (average 36.6 years). There were a total of 95 implants: 36 (37.9%) at the central incisor site, 35 (36.8%) at the lateral incisor site, and 24 (25.3%) at the canine site (Table 1). The IRA ranged from 3 to 40 degrees (20.7 ± 8.5 degrees). In regard to the type of abutment, 76 (80%) were straight, while 19 (20%) were angled. Regardless of abutment type, 72 implants

(75.8%) were within the safe angle, while 23 implants (24.2%) were outside the safe angle (see Table 2).

Associations with Lying Within the Safe Angle

All 19 implants with angled abutments were not within the safe angle, whereas 72 of the 76 implants with straight abutments were within the safe angle (94.7%) and 4 (5.3%) were outside it.

There was a statistically significant association between lying within the safe angle and the type of abutment (*P* < .001; OR = 19), IRA (*P* < .001; effect size = 0.904), difference between IIA and IRA (*P* < .001; effect size = 1.209), and sex (*P* < .0001; OR = 2.995). Straight abutments were 19 times more likely to lie within the safe angle compared to angled abutments. Implants lying within the safe angle showed a statistically significantly higher IRA with a lower difference between IIA and IRA than those not lying within the safe angle. Men showed a threefold higher prevalence of implants lying within the safe angle than women. There was no statistically significant association between lying within the safe angle and IIA (*P* = .757; effect size = 0.063), implant site (*P* = .200; effect size = 0.184), and age (*P* = .387; effect size = 0.208) (Table 2).

Associations with Type of Abutment

There was a statistically significant association between the type of abutment and IRA (*P* = .001; effect size = 0.762) as well as the difference between IIA and IRA (*P* < .001; effect size = 1.056) (Table 3). Angled abutments showed a statistically significantly lower IRA and a higher difference between IIA and IRA than straight abutments.

Multivariate Analysis

Logistic regression analysis for predictors of lying within the safe angle

The binary logistic regression analysis model was constructed to determine significant predictors of lying within the safe angle. The dependent variable was placement within the safe angle, while the independent variables included sex, IRA and the difference between IIA and IRA. The type of abutment (straight/angled) was not included in the model. Although it proved significant results in the univariate analysis, because the implants with angled abutments did not lie within the safe angle, this data could have affected the model. The model fit was proved by the statistically significant -2 log likelihood = 63.267, *P* < .001. Cox and Snell R square and Nagelkerke R square values were 0.357 and 0.533, respectively (Table 4). These results indicate the model fit and describe the relationship between the variables.

The results showed that IRA was a statistically significant positive predictor of lying within the safe angle. Cases with larger IRAs were 1.038 times more likely to lie within the safe angle than those with a smaller angle. The difference between IIA and IRA was a statistically significant negative predictor of lying within the safe angle. Cases with larger differences were 0.702 times less likely to lie within the safe angle than those with smaller differences. Sex was not a statistically significant predictor of lying within the safe angle.

Table 1 Descriptive Demographic Data of Included Participants

	Female	Male	Total
Central incisor	19	17	36 (37.9%)
Lateral incisor	18	17	35 (36.8%)
Canine	15	9	24 (25.3%)
Total	52 (54.7%)	43 (45.3%)	95 (100%)

Table 2 Associations Between Variables and Lying Within the Safe Angle

	Within safe angle (n = 72)	Outside safe angle (n = 23)	*P*	Effect size
Type of abutment, n (%)				
Angled	0 (0%)	19 (100%)	< .001a*	19
Straight	72 (94.7 %)	4 (5.3%)		
IRA, degrees				
Median (range)	22 (6 to 40)	14 (3 to 26)	< .001b*	0.904
Mean ± SD	22.8 ± 8.1	14.3 ± 6.6		
IIA, degrees				
Median (range)	28 (10 to 41)	27 (10 to 45)	.757b	0.063
Mean ± SD	27.5 ± 7.6	27.2 ± 10.2		
Difference between IIA and IRA, degrees				
Median (range)	5 (–9 to 21)	11 (–1 to 27)	< .001b*	1.209
Mean ± SD	4.68 ± 5.29	12.9 ± 6.4		
Age, y				
Mean ± SD	37.6 ± 7.4	36 ± 7.8	.387b	0.208
Sex, n (%)				
Female	35 (48.6%)	17 (73.9 %)	.034c*	2.995
Male	37 (51.4%)	6 (26.1)		
Site, n (%)				
Central incisor	26 (36.1%)	10 (43.5 %)	.200c	0.184
Lateral incisor	30 (41.7%)	5 (21.7%)		
Canine	16 (22.2%)	8 (34.8%)		

a = Fisher's exact test; b = Mann-Whitney *U* test; c = chi-square test; *Significant (*P* ≤ .05).

Table 3 Associations Between Variables and the Type of Abutment

	Straight abutment (n = 76)		Angled abutment (n = 19)			
	Median (range)	Mean ± SD	Median (range)	Mean ± SD	*P*	Effect size (d)
IRA, degrees	22 (5 to 40)	22.3 ± 8.2	13 (3 to 26)	14.4 ± 6.8	.001*	0.762
Difference between IIA and IRA, degrees	5 (–9 to 21)	5 ± 5.36	12 (–1 to 27)	13.32 ± 6.87	< .001*	1.056

*Significant ($P \leq .05$) using Mann-Whitney *U* test.

Table 4 Binary Logistic Regression Analysis for the Significant Predictors of Lying Within the Safe Angle

				95% CI		
Variables	β	SE	OR	Lower limit	Upper limit	*P*
Sex	–1.079	0.702	0.34	0.086	1.346	.124
IRA	0.138	0.051	1.147	1.038	1.269	.007*
Difference between IIA and IRA	–0.230	0.063	0.795	0.702	0.9	< .001*

β = regression coefficient; SE = standard error; OR = odds ratio.
*Significant ($P \leq .05$).

Table 5 Classification Results According to the Discriminant Function of Predicting Lying Within the Safe Angle from Age, Sex, Tooth Type, IRA, IIA, and Type of Abutment

		Predicted		
Safe angle	Observed	Within safe angle	Outside safe angle	Percentage correct
Within safe angle	72	72	0	100%
Outside safe angle	23	4	19	82.6%
Overall percentage correct				95.8%

Table 6 Classification Results According to the Discriminant Function of Predicting Lying Within the Safe Angle from IRA and the Difference Between IIA and IRA

		Predicted		
Safe angle	Observed	Within safe angle	Outside safe angle	Percentage correct
Within safe angle	72	56	16	77.8
Outside safe angle	23	4	19	82.6%
Overall percentage correct				78.9%

Discriminant Function for Predicting Lying Within the Safe Angle Using All Independent Variables

A discriminant analysis was conducted to predict lying within the safe angle (within safe angle = 1, outside safe angle = 0) using the independent variables of age, sex (female = 1, male = 2), tooth type (central incisor = 1, lateral incisor = 2, canine = 3), IRA, IIA, difference between IIA and IRA, and type of abutment (angled = 0, straight = 1). The analysis resulted in the following equation (excluding the difference between IIA and IRA because it was found to be nonsignificant in this analysis):

$$D = 0.035\ \text{Age} + 0.290\ \text{Sex} - 0.231\ \text{Tooth type} + 0.046\ \text{IRA} - 0.033\ \text{IIA} + 5.257\ \text{Abutment type} - 5.522$$

The discriminant functions at group centroids (group means) were 1.177 and –3.683 for lying within and outside the safe angle, respectively. Classification results revealed that 100% of implants lying within the safe angle and 82.6% of implants lying outside the safe angle were correctly classified according to the previous discriminant function. The overall correct classification was 95.8% (Table 5).

Discriminant Function for Predicting Lying Within the Safe Angle Using Significant Predictors Obtained from Logistic Regression Analysis

A discriminant analysis was conducted to predict lying within the safe angle (within safe angle = 1, outside safe angle = 0) using significant predictors obtained from the binary logistic regression analysis, including the IRA and the difference between IIA and IRA. The analysis resulted in the following equation:

$$D = 0.298 - 0.059\ \text{IRA} + 0.139\ \text{Difference between IIA and IRA}$$

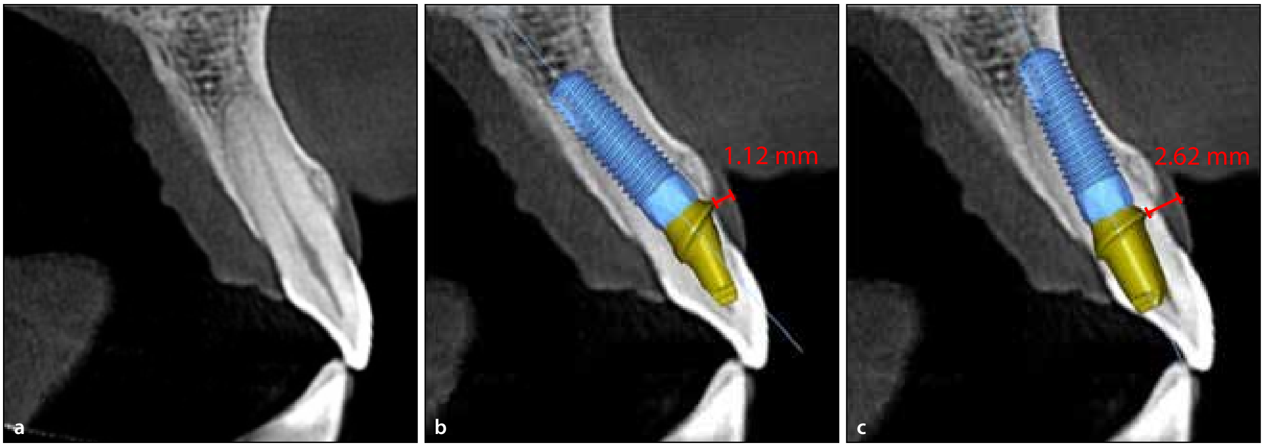

Fig 5 CBCT cross-sectional cuts of a maxillary lateral incisor. *(a)* Cross-sectional view of a maxillary lateral incisor showing soft tissue thickness on the labial aspect of the tooth. *(b)* Simulation of an immediate implant engaging the palatal bone, with a long axis labial to the incisal edge, using an angled abutment and resulting in a reduced soft tissue gap coronal to the implant-abutment interface. *(c)* Simulation of an immediate implant with a long axis slightly palatal to the incisal edge using a straight abutment and resulting in an adequate soft tissue gap coronal to the implant-abutment interface.

The discriminant functions at group centroids (group means) were –0.397 and 1.243 for lying within and outside the safe angle, respectively. Classification results revealed that 77.8% of implants within the safe angle and 82.6% of implants outside the safe angle were correctly classified according to this discriminant function. The overall correct classification was 78.9% (Table 6).

DISCUSSION

The 3D positioning of immediate implants in the anterior maxilla is influenced by tooth root angulation and its relation to the alveolar housing.[31] The alveolar bone in the anterior maxilla is usually proclined in an anterior-inferior direction, forming a concavity apical to the labial apices of the anterior teeth.[32] This labial bone concavity was found to be at a depth of around 2.8 mm.[33] Moreover, it was reported that the long axis of teeth in the anterior maxilla and their alveolar bone form a divergent angle ranging from 10 to 30 degrees.[34] This may pose a challenge when trying to achieve the correct implant position in the anterior maxilla without jeopardizing the facial bone housing of the socket.[35] In their simulated CBCT study Botermans et al[36] reported an 80% incidence of labial perforation when implants were planned in a prosthetically driven position. Compromising the proper prosthetically driven position might necessitate the need for an angled abutment to meet the future prosthetic incisal edge location.[20,37]

The present study used a new method for IIP position assessment called the "safe angle concept" that is based on the original IRA of the natural tooth in relation to the type of abutment used (straight/angled). Using initial and postoperative CBCTs, 95 immediate implants in the anterior maxilla were analyzed. The results showed that 80% of the abutments used were straight, while 20% were angled.

Furthermore, there was a significant association between the type of abutment used and whether the implant was positioned within the safe angle; 95% of implants with straight abutments were within the safe angle, while all implants with angled abutments were outside it. Implants with straight abutments were 19 times more likely to lie within the safe angle compared to implants with angled abutments.

Traditionally, it has been recommended to place the immediate anterior implant in a more palatal position with at least a 2-mm labial gap.[38,39] Insisting on having this gap during implant placement might increase the incidence of unfavorable labial inclination of the implant and the need for an angled abutment in the final prosthetic construction. This might explain the higher incidence of angled abutments in the virtually simulated studies done by Kan et al[20] and Edmondson et al.[37] Kan et al reported 16% straight and 84% angled abutments, and Edmondson et al reported 24% straight and 76% angled abutments.

Even though angled abutments in the anterior maxilla are used to correct the labial implant inclination, this may result in a reduction of the soft tissue gap coronal to the implant-abutment interface, thus limiting the horizontal supracrestal dimension of the emergence profile[27] (Fig 5). It was also reported that the implant-abutment angle and abutment-crown angle are influenced by the labiopalatal implant position. An abutment-crown angle of more than 25 degrees can increase the risk of marginal soft tissue recession.[40]

In order to achieve the proper immediate implant position in the anterior maxilla, Kan et al[14] found that the anatomical sagittal root position in the arch was a predictable prerequisite factor for planning. They suggested that class I is the most favorable clinical situation, where a considerable amount of bone is present on the palatal aspect for implant engagement to attain primary stability. On the contrary, the present study did not use the sagittal root position as a reference for implant placement. All implants were placed with their long axis palatal to the incisal edge of the future restoration to ensure prosthetically driven placement. Interestingly, the statistical analysis of the present study showed a significant association between the original IRA and the type of abutment used, and therefore, it could be a supplementary predictor of the immediate implant position in the anterior maxilla. Angled abutment cases were associated with a reduced original mean IRA of 14.4 degrees, while straight abutment cases had an original mean IRA of 22.3 degrees.

This data emphasizes the importance of the original incisal edge position as a determinant for successful prosthetic planning of IIP position in the anterior maxilla. In accordance with that, Testori et al[41] highlighted that the most appropriate implant position is when the long axis of the implant is aimed at the incisal edge of the future restoration. Furthermore, a centered implant placement directed toward the incisal edge and aligned with the same axis of the natural tooth has a better long-term outcome and facilitates prosthesis fabrication.[42] Moreover, Wang et al[43] and Chung et al[44] suggested that implants placed in the anterior maxilla should mimic and parallel the natural contralateral tooth root axis but should be located more palatal due to the thicker palatal native bone.

It is well documented that labiopalatal inclination of the root may influence IIP position and consequently the type of abutment used. Several previous studies have shown that most maxillary teeth (almost 80%) are retroclined and positioned directly up against the facial bone plate.[14,15] This may lead to a 10- to 30-degree labial implant inclination.[34] The present study measured the original IRA to represent root inclination and the IIA to represent implant inclination. Remarkably, the data revealed that the lower the difference between these angles, the more straight abutments were used. This highlights the importance of root inclination as an additional predictive element in IIP position in the anterior maxilla.

Regarding the type of abutment used and site, Edmondson et al[37] reported more angled abutment used in the lateral incisor position. This might be related to the smaller alveolar width and the presence of labial undercuts at the lateral incisor area.[45,46] On the contrary, the present data showed no statistically significant association between site location and position within the safe angle and subsequently the type of abutment used. This might be explained by the relatively smaller number of anterior teeth included.

To the authors' knowledge, no studies have analyzed the discriminant function of predictors for immediate implant position in the anterior maxilla. Using discriminant analysis, an optimal set of predictors was identified that determined whether the implants would be within the safe angle or not. The resulting discriminant function can be easily implemented as a computer-mediated decision aid. The advantages of such a tool are simplicity, ease of implementation, and use of predictive variables readily available during planning for IIP. In the present study, two discriminant analyses were conducted; the first one used all independent variables including age, sex, tooth type, IRA, IIA, and type of abutment, with an overall correct classification rate of 95.8%. The second discriminant analysis used only the significant predictors, including IRA and the difference between IIA and IRA. Model performance demonstrated promising results in the prediction of implant position within the safe angle (77.8%). The results showed that the predictive feature set can potentially improve clinical decision support by promoting personalized treatment planning, optimizing dental implant treatment, and minimizing the unfavorable labial implant inclination.

The present authors propose the use of the "safe angle concept" during planning for IIP in the anterior maxilla. The re-creation of the incisal edge for measuring IRA can be accomplished through virtual surgical planning software or clinically by fabricating clear plastic retainers that restore the coronal tooth structure for the missing tooth prior to performing a CBCT scan.

This study had a few methodologic limitations worth mentioning. The intrinsic nature of radiographic examination by itself shows minimal underestimation or overestimation when radiographic measurements are compared with direct measurements, especially in the presence of metallic artifact.[47] All implants were placed using a freehand method without assessing the possible angular deviation during implant placement.[48,49] The small number of included CBCT scans is another limitation of this study. Further clinical investigations are recommended to assess the effect of the "safe angle concept" on the final esthetic outcome.

CONCLUSIONS

The "safe angle concept" can be used as a reliable planning tool to determine the correct IIP position in the anterior maxilla. Applying the safe angle concept will decrease the need to use angled abutments for prosthetic correction. There was a significant association between the type of abutment used and implant position within the safe angle; in 95% of cases with straight abutments, the implants were lying within the safe angle, while 100% of the implants with angled abutments were outside the safe angle.

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