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CLINICAL RESEARCH

Characterization of the anterior maxillary region for immediate implant placement: A radiographic cross-sectional study

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ABSTRACT

Statement of problem. Information regarding the influence of local phenotypical features in the context of immediate implant placement (IIP) in the anterior maxillary region is sparse.

Purpose. The purpose of this clinical study was to characterize key phenotypical and anatomical characteristics of the anterior maxilla related to the feasibility of virtual IIP.

Material and methods. Cone beam computed tomography (CBCT) scans acquired from adult participants were used for virtual implant placement and to measure periodontal phenotypical dimensions (buccal and palatal gingival (GT) and bone thickness (BT)), the buccal gap (BG) at different apico-coronal levels, and anatomical variables nasopalatine canal and ramifications, nasal cavity, maxillary sinus). The study sample was comprised of 330 maxillary anterior teeth. Two different immediate implant modalities were examined: cingulum emergence plan (CEP) and incisal edge emergence plan (IEP).

Results. A total of 660 implants were virtually placed. The mean periodontal phenotypical dimensions showed variability between and within individuals depending on the apico-coronal level, tooth type, and implant placement modality. Immediate implant feasibility was 90.1% and 93.6% for the CEP and IEP groups, respectively, and was influenced by tooth type and anatomical variables. BG distance was generally greater at the coronal aspect and in the CEP. Thick bone and gingiva (≥1 mm) were observed in 15.2% and 89.3% of the sites, respectively. A minimum of 2 mm of apical bone availability to achieve primary stability was observed in 88.8% and 91.2% of the sites in the CEP and IEP groups, respectively.

Conclusions. This study highlights the variability in periodontal phenotypical and local anatomical features at anterior maxillary sites. These observations underscore the importance of recognizing such variations that should be identified and considered during the planning and execution of therapy. (J Prosthet Dent xxxx;xxx:xxx-xxx)

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Clinical Implications

Periodontal phenotypical dimensions varied between and within individuals and according to the apico-coronal level, tooth type, and whether the immediate implant is positioned according to a restorative plan compatible with a CEP or IEP. Although the feasibility of implant placement was similar between placement methods, IEP was associated with greater BG dimensions and a reduced risk of buccal bone fenestration. However, a reduction in the likelihood of invading the nasopalatine canal or its ramifications was observed in a CEP implant position. This information could be used to make adequate clinical decisions in the context of IIP since it could affect long-term health, function, and esthetics.

Implant-supported single-tooth fixed prostheses in the anterior maxilla have consolidated globally as a treatment option that is generally associated with satisfactory health, functional, and esthetic outcomes.[1–3] Different treatment options for implant placement after tooth extraction include immediate placement or placement shortly after tooth extraction (<10 days),[4] after soft tissue healing (4 to 8 weeks), after the majority of post-extraction alveolar ridge remodeling has taken place,[5] after completion of soft tissue maturation (12 to 16 weeks), or alveolar bone healing (>16 weeks).[6]

Immediate implant placement (IIP) has been considered a suitable and successful protocol.[7–17] Nevertheless, understanding the effect that local anatomical and phenotypical features surrounding the extraction may have on the feasibility of implant placement and on the remodeling of the alveolar ridge after tooth extraction is fundamental to make adequate clinical decisions.[4,18–28] The periodontal phenotype (PP) encompasses the gingival phenotype, comprised of the keratinized tissue width (KTW) and gingival thickness (GT), and the bone morphotype, which is depicted by bone thickness (BT).[29–36] Recent evidence suggests that supracrestal soft tissue height should also be considered an integral component of the PP as it has been correlated with other periodontal and tooth-related variables, as well as with the degree of post-extraction alveolar bone resorption.[21,37] Therefore, evaluating site-specific characteristics before and upon tooth extraction is particularly important in situations related to IIP.[38–40]

Although different studies have evaluated the feasibility of IIP in the esthetic maxillary region according to different restorative treatment options utilizing cone beam computed tomographic (CBCT) scans,[41–43] evidence on the impact of local phenotypical features in IIP is lacking. Hence, this study aimed to characterize several key phenotypical and anatomical features of the anterior maxilla and to determine the feasibility of virtual IIP. The null hypothesis was that local phenotypical features would not have an influence on the feasibility of virtual IIP.

MATERIAL AND METHODS

The clinical evaluation of this study took place in the Department of Periodontics at Fluminense Federal University (Brazil) between January 2016 and September 2023 and followed the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.[44] The experimental protocol had been approved by the Fluminense Federal University (CEP/HUAP/UFF #506.300).

Eligibility criteria have been reported in previous studies, including part of this patient cohort.[31,35,37] Further details on the methodology, including eligibility criteria, clinical and digital collection, digital and statistical analyses, and sample size calculation, can be found in Figures 1–3, and in Supplemental Material 1 (available online).

RESULTS

A total of 55 participants were included in the study, of whom 16 were men (29.1%) and 39 women (70.9%). The mean ±standard deviation age was 33.4 ±13 years (range 18 to 71 years). Fourteen participants were Black, and 39 were White.

A total of 330 permanent maxillary anterior teeth (110 central incisors, 110 lateral incisors, and 110 canines) compromised the sample in this study. Therefore, 660 implants were virtually positioned: 330 of them according to a cingulum emergence plan (CEP) and 330 following an incisal edge emergence plan (IEP). Mean values of PP features according to tooth type and apico-coronal landmarks prior to virtual IIP and the classification of sites according to the sagittal root position (SRP) are depicted in Table 1.

For IIP following a CEP, buccal and palatal BT varied among apico-coronal levels and between and within individuals, as shown in Table 2. At the platform, middle, and apical part of the implant, overall buccal bone thickness (BBT) was 0.9 ±0.4 mm, 0.6 ±0.4 mm, and 2 ±1 mm, respectively. Similarly, at the platform, middle, and apical part of the implant's overall palatal bone thickness (PBT) was 1.1 ±0.6 mm, 3.2 ±1.7 mm, and 6.7 ±3 mm, respectively.

Buccal and palatal GT also varied among apico-coronal levels and between and within individuals. The overall buccal GT at the platform and middle parts of the implant were 0.6 ±0.3 mm and 1.2 ±0.7 mm, respectively. The mean palatal GT at the platform and middle

Table 1. Mean periodontal phenotypical values according to tooth type and apico-coronal landmarks, and classification of sites according to sagittal root position

		Central Incisors	Lateral Incisors	Canines	Mean
PP dimensions Mean (SD)	GT2-GM	1.5 (0.3)	1.2 (0.3)	1.2 (0.3)	1.3 (0.3)
	GT-BBC	0.9 (0.3)	0.8 (0.3)	0.6 (0.2)	0.8 (0.3)
	GT1-BBC	0.7(0.3)	0.6 (0.3)	0.5 (0.2)	0.6 (0.3)
	GT3-BBC	0.7 (0.3)	0.6 (0.2)	0.5 (0.2)	0.6 (2.5)
	KTW	4.5 (1.1)	4.9 (1.4)	4.2 (1.4)	4.5 (1.3)
	BT-BBC	0.6 (0.2)	0.6 (0.2)	0.6 (0.2)	0.6 (0.2)
	BT1-BBC	0.7 (0.2)	0.7 (0.3)	0.7 (0.3)	0.7 (0.3)
	BT3-BBC	0.7 (0.3)	0.8 (0.4)	0.7 (0.4)	0.7 (0.4)
	GT2-PGM	2.1 (0.5)	2.1 (0.5)	2.2 (0.5)	2.1 (0.5)
	GT-PBC	2.3 (0.7)	2.5 (0.7)	2.5 (0.7)	2.4 (0.7)
	GT1-PBC	2.3 (0.6)	2.6 (0.7)	2.8 (0.7)	2.5 (0.7)
	GT3-PBC	2.5 (0.7)	2.9 (0.7)	3.3 (0.7)	3.0 (0.7)
	BT-PBC	0.7 (0.2)	0.6 (0.2)	0.7 (0.3)	0.7 (0.2)
	BT1-PBC	1.0 (0.4)	0.9 (0.3)	0.9 (0.4)	0.9 (0.3)
	BT3-PBC	1.5 (0.6)	1.2 (0.5)	1.2 (0.5)	1.3 (0.5)
SRP (%)	I	74.5%	51.9%	73.6%	66%
	II	17.3%	13%	12.8%	15%
	III	_	_	_	_
	IV	8.2%	35.1%	13.6%	19%

BT-BBC, buccal bone thickness at the level of the bone crest; BT-PBC; palatal bone thickness at the level of the bone crest; BT1-BBC; buccal bone thickness 1 mm apical to the bone crest; BT1-PBC; palatal bone thickness 1 mm apical to the bone crest; BT3-BBC; buccal bone thickness 3 mm apical to the bone crest; BT3-PBC; palatal bone thickness 3 mm apical to the bone crest; GT-BBC; buccal gingival thickness at the level of the bone crest; GT-PBC; palatal gingival thickness at the level of the bone crest; GT1-BBC; buccal gingival thickness 1 mm apical to the bone crest; GT1-PBC; palatal gingival thickness 1 mm apical to the bone crest; GT2-GM; buccal gingival thickness 2 mm apical to the gingival margin; GT2-PGM; palatal gingival thickness 2 mm apical to the gingival margin; GT3-BBC; buccal gingival thickness 3 mm apical to the bone crest; GT3-PBC; palatal gingival thickness 3 mm apical to the bone crest; KTW; mid-facial keratinized tissue width; PP; periodontal phenotype; SRP; sagittal root position.

region of the implant were 3 ±0.8 mm and 3 ±1.1 mm, respectively. The results by tooth type are shown in Table 2.

IIP was deemed virtually feasible in 90.1% of the study sites, specifically in 94.5% of the maxillary central incisors, 87% of the maxillary lateral incisors, and 89% of the maxillary canines. Implant length at the central incisors ranged between 10 and 14 mm, being 12 mm the most frequent (63%), followed by 10 mm (29%), and 14 mm (8%); at the lateral incisors it ranged between 10

Table 2. Mean bone and soft tissue values and buccal gap distance in relation to virtual implant position modality and apico-coronal landmarks

			Central Incisors	Lateral Incisors	Canines	Overall
Cingulum Emergence Plan	Bone Dimensions Mean (SD)	BBT-platform	0.8 (0.3)	1 (0.5)	0.9 (0.5)	0.9 (0.4)
		BBT-middle	0.7 (0.3)	0.6 (0.5)	0.6 (0.3)	0.6 (0.4)
		BBT-apical	2.1 (1)	1.7 (0.9)	2.2 (0.3)	2.0 (1.0)
		PBT-platform	1.2 (0.5)	1 (0.6)	1.1 (0.8)	1.1 (0.6)
		PBT-middle	2.9 (1.7)	3.1 (1.5)	3.6 (1.9)	3.2 (1.7)
		PBT-apical	6 (3)	6.5 (2.6)	7.8 (3)	6.7 (3.0)
	Soft Tissue Dimensions Mean (SD)	BST-platform	0.7 (0.3)	0.7 (0.4)	0.5 (0.2)	0.6 (0.3)
		BST-middle	3.1 (0.6)	3.1 (0.6)	3.1 (0.6)	1.2 (0.7)
		PST-platform	2.6 (0.6)	3.1 (0.6)	3.5 (0.8)	3.0 (0.8)
		PST-middle	2.5 (1)	2.7 (0.8)	3.7 (1.2)	3.0 (1.1)
	Buccal Gap Distance Mean (SD)	Platform	2.3 (0.5)	2.7 (0.5)	3.4 (0.6)	2.8 (0.7)
		Middle	1.3 (0.6)	1.3 (0.6)	2.1 (0.7)	1.6 (0.7)
Incisal Edge Emergence Plan	Bone Dimensions Mean (SD)	BBT-platform	0.8 (0.3)	1 (0.5)	0.9 (0.5)	0.9 (0.4)
		BBT-middle	0.7 (0.4)	0.6 (0.4)	0.7 (0.4)	0.6 (0.4)
		BBT-apical	3 (1.2)	2.7 (1.2)	2.9 (1.2)	2.9 (1.2)
		PBT-platform	1.6 (0.5)	1.3 (0.6)	1.7 (0.8)	1.5 (0.6)
		PBT-middle	2.6 (1.3)	2.6 (1.3)	3.2 (1.7)	2.8 (1.5)
		PBT-apical	5.1 (2.4)	5 (2.4)	6.7 (3.2)	5.6 (2.8)
	Soft Tissue Dimensions Mean (SD)	BST-platform	0.7 (0.3)	0.6 (0.3)	0.6 (0.5)	0.6 (0.4)
		BST-middle	1.3 (0.6)	1.4 (0.6)	1.2 (0.9)	1.3 (0.7)
		PST-platform	2.5 (0.6)	2.9 (0.7)	3.4 (0.8)	2.9 (0.8)
		PST-middle	2.2 (1)	2.8 (0.8)	3.5 (1)	2.9 (1.0)
	Buccal Gap Distance Mean (SD)	Platform	1.7 (0.5)	2.1 (0.5)	2.6 (0.6)	2.1 (0.7)
		Middle	1.3 (0.7)	1.4 (0.6)	1.9 (0.7)	1.5 (0.7)

BBT-apical; buccal bone thickness at the apical level of the implant; BBT-middle; buccal bone thickness at the middle part of the implant; BBT-platform; buccal bone thickness at the level of the implant platform; BST-apical; buccal soft tissue thickness at the apical level of the implant; BST-middle; buccal soft tissue thickness at the middle part of the implant; BST-platform; buccal soft tissue thickness at the level of the implant platform; PBT-apical; palatal bone thickness at the apical level of the implant; PBT-middle; palatal bone thickness at the middle part of the implant; PBT-platform; palatal bone thickness at the level of the implant platform; PST-apical; palatal soft tissue thickness at the apical level of the implant; PST-middle; palatal soft tissue thickness at the middle part of the implant; PST-platform; palatal soft tissue thickness at the level of the implant platform.

Table 3. Feasibility of implant placement and reasons why implants were deemed unfeasible

			Central Incisors	Lateral Incisors	Canines
Cingulum Emergence Plan	Feasibility of Implant Placement (%)		94.5 90.1	87	89
	Reasons Why Implants were Deemed Unfeasible (%)	Violation of the Nasopalatine Canal	15.4	-	-
		Sinus Perforation	-	-	5.5
		Fenestration at the Middle or Apical Region of the Alveolus	1.1	11	6.6
		Perforation of the Nasal Cavity	1.1	1.1	-
		SRP I	4.9	9.6	4.9
		SRP II	-	-	7.4
		SRP III	-	-	-
		SRP IV	22.2	21.1	40
Incisal Edge Emergence Plan	Feasibility of Implant Placement (%)		91 93.6	97	93
	Reasons Why Implants were Deemed Unfeasible (%)	Violation of the Nasopalatine Canal	19.8	-	-
		Sinus Perforation	-	-	5.5
		Fenestration at the Middle or Apical Region of the Alveolus	2.2	2.2	2.2
		Perforation of the Nasal Cavity	1.1	1.1	-
		SRP I	33.3	3.8	1.2
		SRP II	15.8	-	14.3
		SRP III	-	-	-
		SRP IV	22.2	2.7	26.7

SRP, sagittal root position.

and 14 mm, being 12 mm the most frequent (62%), followed by 10 mm (31%), and 14 mm (7%). At the canines, it ranged between 10 and 18 mm, being 14 mm the most frequent (37%), followed by 12 mm (27%), 10 mm (16%), 16 mm (16%), and 18 mm (3%). Reasons to deem virtual IIP unfeasible included violation of the nasopalatine canal (14 central incisors), sinus perforation (5 canines), fenestration at the middle or apical region of the alveolus (1 central incisors, 10 laterals, 6 canines), and perforation of the nasal cavity (1 central incisor, and 1 lateral incisor), as depicted in Table 3. The relationship between SRP and the feasibility of implant placement is shown in Table 3.

The buccal gap (BG) dimensions at the platform and middle regions of the implant were 2.3 ±0.5 mm and 1.3 ±0.6 mm at central incisor sites, 2.7 ±0.5 mm and 1.3 ±0.6 mm at lateral incisor sites, and 3.4 ±0.6 mm and 2.1 ±0.7 mm at canine sites, respectively, as shown in Table 2.

Distance to the nasopalatine canal at the level of the central incisors varied at different apico-coronal levels. At the platform, it was 1.1 ±0.6 mm (range: 0.1 to 3.9 mm); in the middle, it was 1.4 ±0.7 mm (range: 0 to 3.5 mm); and in the apical region, it was 2.4 ±1.3 mm (range: 0.2 to 5.7 mm).

Similar to the observations in the CEP group, buccal and palatal BT varied among apico-coronal levels and between and within individuals (Table 2). At the platform, middle, and apical regions of the implant, mean ±standard deviation buccal BT was 0.9 ±0.4 mm, 0.6 ±0.4 mm, and 2.9 ±1.2 mm, respectively. Similarly, at the platform, middle, and apical regions of the implant, mean ±standard deviation palatal BT was 1.5 ±0.6 mm, 2.8 ±1.5 mm, and 5.6 ±2.8 mm, respectively.

Buccal and palatal GT varied among apico-coronal levels and between and within individuals. The mean ±standard deviation buccal GT at the platform and middle regions of the implant was 0.6 ±0.4 mm and 1.3 ±0.7 mm, respectively. The mean ±standard deviation palatal GT at the platform and middle regions of the implant was 2.9 ±0.8 mm and 2.9 ±1 mm, respectively. Results by tooth type are shown in Table 2.

IIP was deemed virtually feasible in 93.6% of the study sites, specifically in 91% of the central incisors, 97% of the lateral incisors, and 93% of the canines. Implant length at the central incisors ranged between 10 and 14 mm, with 12 mm being the most frequent (61%), followed by 10 mm (30%), and 14 mm (9%); at the lateral incisors it ranged between 10 and 14 mm, with 12 mm being the most frequent (57%), followed by 10 mm (34%), and 14 mm (9%). At the canines it ranged between 10 and 18 mm, with 14 mm being the most selected one (44%), followed by 12 mm (29%), 16 mm (13%), 10 mm (8%), and 18 mm (6%). Reasons to deem virtual IIP unfeasible included violation of the nasopalatine canal (18 central incisors), sinus perforation (5 canines), fenestration at the middle or apical part of the alveolus (2 central incisors, 2 lateral incisors, 2 canines), and perforation of the nasal cavity (1 central incisor, 1 lateral incisor). The relationship between SRP and the feasibility of implant placement is shown in Table 3.

The BG dimensions at the platform and middle regions of the implant varied across different sites, as shown in Table 2. At central incisor sites, the dimensions were 1.7 ±0.5 mm and 1.3 ±0.7 mm, respectively. For lateral incisors, these values increased to 2.1 ±0.5 mm and 1.4 ±0.6 mm, while at canine sites, they were the highest, measuring 2.6 ±0.6 mm and 1.9 ±0.7 mm.

The distance to the nasopalatine canal at the level of the central incisors varied at different apico-coronal

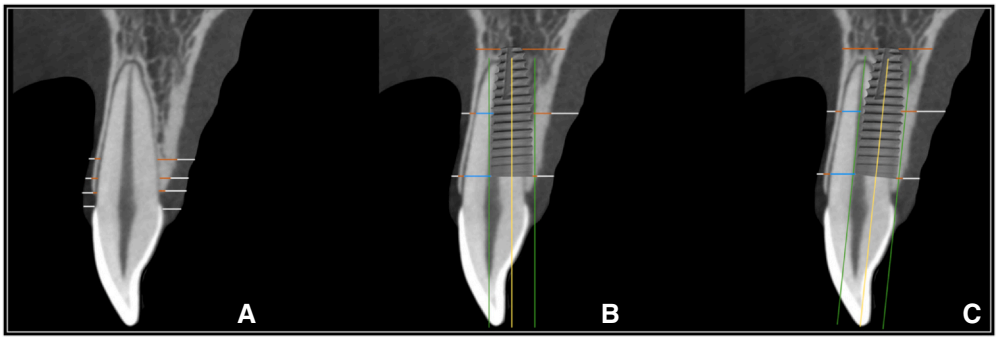

Figure 1. Sagittal radiographic sections demonstrate method followed to assess dimensions of buccal and palatal bone (*orange line*) and soft tissue (*white line*) at different apico-coronal landmarks. Buccal and palatal bone (*orange line*) and soft tissue thickness (*white lines*) at different apico-coronal landmarks, and buccal gap distance (*blue line*) at most coronal and middle regions of implant. A, At baseline. B, When implant placed according to cingulum emergence plan. C. When implant placed according to incisal edge emergence plan.

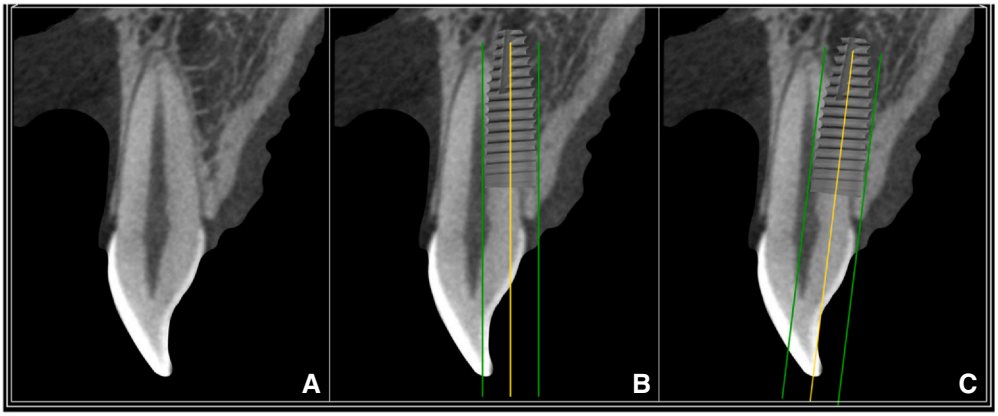

Figure 2. A, Methodology followed to determine region of interest. B, Virtual implant placement in prosthetically and anatomically favorable location according to cingulum emergence plan. C, According to incisal edge emergence plan.

levels. At the platform, it was 1.5 ±0.4 mm (range: 0.6 to 2.5 mm); in the middle, it was 1.3 ±0.6 mm (range: 0 to 2.8 mm); and in the apical region, it was 1.9 ±1.1 mm (range: 0 to 5 mm). When the sites were categorized based on the buccal BT measured at 1 mm apical to the bone crest, a thick phenotype (≥1 mm), which can be generally considered favorable for IIP, was observed in only 50 sites, representing 15.2% of the sample (12 central incisors, 20 lateral incisors, and 18 canines). Nevertheless, when the sites were categorized based on the buccal GT measured at 2 mm apical to the gingival margin, a thick phenotype (≥1 mm), which can be generally considered favorable for IIP, was observed in 295 sites, representing 89.3% of the sample (109 central

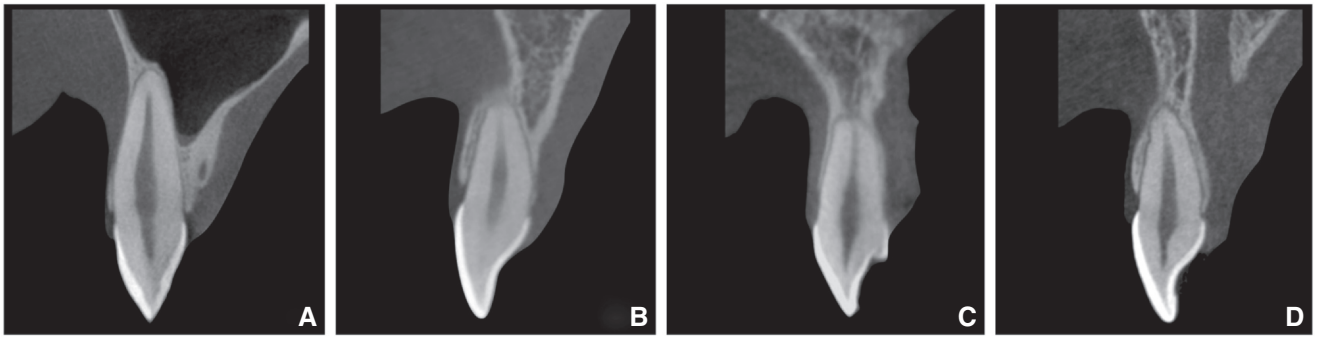

Figure 3. Clinical scenarios where implant placement deemed not feasible, A, Because of potential perforation of maxillary sinus. B, Because of apical perforation of alveolar ridge. C, Because of palatal bone dehiscence. D, Because of fenestration at apical buccal and palatal sites with violation of nasopalatine canal.

incisors, 100 lateral incisors, and 86 canines). When the sites were analyzed according to apical bone availability for achieving mechanical stability in the absence of fenestrations or violation of anatomical structures, virtual IIP was deemed unfeasible in 37 (11.2%) and 29 (8.8%) of the sites in the CEP and IEP groups, respectively, indicating that a minimum of 2 mm of apical bone availability to achieve primary stability was observed in 88.8% and 91.2% of the sites in the CEP and IEP groups, respectively.

DISCUSSION

The authors are unaware of a previous cross-sectional study characterizing the phenotypical features at different apico-coronal landmarks of the anterior maxillary region in the context of IIP. The null hypothesis that local phenotypical features would not have an influence on the feasibility of virtual IIP was rejected since the dimensions of GT, BT, and BG varied depending on apico-coronal level and tooth type and had a direct influence on IIP planning. These observations were consistent with studies on the characterization of the PP, where variations in the dimensions of the BT and GT were reported at different apico-coronal levels.[30–34,37] In addition, the relative BT and GT at different apico-coronal levels also varied depending on the implant placement modality (CEP or IEP). Additionally, anatomical factors such as SRP, nasopalatine canal, ridge dimensions, and maxillary sinus cavity influenced IIP feasibility, regardless of the virtual placement modality. Together, these findings underlined the importance of a meticulous and judicious assessment of the phenotypical and anatomical features of a future extraction site when IIP is considered.

Virtual IIP was deemed feasible in 90.1% and 93.6% of sites, according to CEP and IEP, respectively. These observations were comparable to those described by González-Martin and Veltri,[41] where IIP was considered possible in 89% of the patients. However, when central incisors were evaluated, IIP was feasible in 94.5% and 91% of the sites according to a CEP or IEP, respectively. Nonetheless, these findings differed from those reported by Chung et al,[43] who observed that 82% of central incisor sites evaluated were compatible with IIP using a Ø5-mm implant, or by Kan et al[42] who reported an 84% IIP feasibility. The feasibility of virtual IIP was also influenced by the SRP, tooth type, and implant positioning. The relationship between SRP and the feasibility of implant placement could be because of its correlation with specific PP dimensions, as reported in previous studies.[31,32] Conversely, the SRP classification presents a level of subjectivity.[39] Nonetheless, the dissimilarities between studies could also be elucidated because of variations in the criteria employed to define IIP feasibility (for example, a minimum of 2 mm apical to the root apex to achieve primary mechanical stability, implant surrounding by bone, and no perforation or violation of anatomical structures).

The authors are unaware of a previous study that evaluated the PP dimensions in conjunction with virtual IIP to determine favorable and unfavorable situations. Sites were categorized as having a thin (<1 mm) or thick (≥1 mm) BT based on the findings of previous studies.[19,21,34] Thick BT and GT (≥1 mm), which can be generally considered favorable for IIP, was observed in 15.2% and 89.3% of the sites, respectively. A minimum of 2 mm of apical bone availability to achieve primary stability was observed in 88.8% and 91.2% of the sites in the CEP and IEP groups, respectively. These findings also underscore the importance of carefully assessing the recipient region when IIP is considered as an option.

Assessment of virtual IIP with a CEP revealed a trend towards a greater risk of buccal bone fenestration at lateral incisor and canine sites. Although both virtual implant placement modalities showed a similar prevalence of violation of the nasopalatine canal, IEP was associated with a slightly greater chance of penetration in the canal or ramifications compared with CEP (19.8% and 15.4%, respectively).

The IIP modality did not seem to affect the likelihood of perforating the maxillary sinus or nasal cavity. Nevertheless, no dissimilarities regarding implant length to achieve mechanical stability were observed among groups. The authors are unaware of a previous investigation that evaluated the presence of the nasopalatine canal and its ramifications, and other relevant anatomical components, in the context of IIP at the level of the central incisors. These anatomical structures should be carefully identified and evaluated during the treatment planning phase utilizing high-quality imaging such as a CBCT scan. Furthermore, to minimize the risk of intraoperative and postoperative complications, computer-assisted implant placement should be used in certain situations, acknowledging the many variables that may influence accuracy.[45–49]

The dimensions of the BG were digitally assessed at the most coronal and middle regions respective to the implant shoulder. As observed with the PP features, BG varied depending on tooth type, implant position, and the apico-coronal level where it was measured. Higher mean values were consistently observed at the most coronal part as compared with the middle region and when the implant was placed according to a CEP, independently of the tooth type. These observations were similar to those reported in a recently published study in which the BG dimensions were measured at 1, 2, and 4 mm apical to the bone crest.[15] This information should be considered when making clinical decisions regarding IIP since the BG distance obtained at the implant

platform level has been correlated with the healing dynamics and future peri-implant BT.[4,12–14,16,40] Therefore, in sites with a thin bone phenotype and when the BG can be grafted, alveolar ridge preservation therapies should be performed.

Limitations of this study included that it focused solely on maxillary anterior teeth with an intact, healthy periodontium, a choice made to standardize study sites and mitigate the impact of various anatomical factors.[23–25] In addition, the patient cohort represented only 2 racial backgrounds. Therefore, the findings should be extrapolated to other populations with caution. Although digital measurement of the BT and GT may be considered a limitation, several studies have demonstrated that the use of CBCT is a reliable and reproducible method.[27,36,50] While virtual IIP was done following rigorous criteria, with calibrated and experienced examiners in this study, this method may not be fully reproducible in other settings because of different educational backgrounds or levels of expertise.[17] The findings of this investigation emphasize the need for further well-designed clinical studies, incorporating adequate and reproducible assessment methods on the topic of IIP to investigate the effect of key local phenotypical characteristics, anatomical variables, and BG dimensions at different apico-coronal levels on a comprehensive set of outcomes of interest.[27,28,51]

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. Mean PP dimensions appeared to vary between and within individuals, influenced by factors such as the apico-coronal level, tooth type, and IIP modality.
2. Both modalities of placement demonstrated similar feasibility for virtual IIP.
3. A tendency for greater BG dimensions at the coronal and middle parts was noted when implants were positioned for straight screw-retained placement compared to positioning toward the incisal edge.
4. IIP following an IEP was associated with a reduced risk of buccal bone fenestration, whereas a lower likelihood of nasopalatine canal invasion at central incisor sites was observed when IIP was performed according to a CEP.

AUTHORS' CONTRIBUTIONS

Emilio Couso-Queiruga and Diogo Moreira-Rodrigues conceived and designed the idea. Emilio Couso-Queiruga, Gustavo Avila-Ortiz, Ignacio Pedrinaci, Rodrigo Lima Petersen, and Diogo Moreira-Rodrigues contributed to data acquisition and analysis. Emilio Couso-Queiruga led the writing. Vivanne Chappuis, Eliane Porto Barboza, and Clemens Raabe contributed to data analysis. All authors critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects of the scientific work.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2025.02.025.

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