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CLINICAL RESEARCH

Proposal regarding horizontal and vertical positioning of single implants placed in healed sites: Effect on cervical crown form and the need for bone grafting

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ABSTRACT

Statement of problem. When single implants are placed in healed sites, guidelines are lacking on the horizontal and vertical implant positions that optimize cervical crown form and the implant locations that would require bone grafting to develop the optimal crown form.

Purpose. The purpose of this clinical study was to evaluate the cervical contour of wax patterns formed on casts of single implants placed in healed sites and to determine which horizontal and vertical implant positions produced the best cervical crown form and which indicated the need for bone grafting.

Material and methods. Fifty-eight wax patterns were fabricated on casts where implants had been placed in healed sites without bone grafting. The wax patterns were subjectively assessed by 5 dental faculty members and 5 graduate students as having good, fair, or poor cervical crown form. Horizontal measurements were made between the facial surface of the implant and a round metal wire connecting the gingival zeniths of the adjacent teeth. Vertical measurements were also made between the wire and implant platform. The subjective assessments along with the horizontal and vertical implant position measurements were used to propose guidelines for optimal implant placement in healed sites.

Results. Horizontal distances of 2.0 to 3.0 mm produced good cervical crown contours, with distances > 3.0 mm and < 2.0 mm resulting in fair or poor assessments. Vertical distances of 3.0 to 4.0 mm were judged to have good cervical crown contour, whereas depths of 1.0 mm or less were assessed as poor.

Conclusions. Based on the subjective assessment of wax patterns formed on casts of single implants placed in healed sites, a guideline of 2.0 to 3.0 mm is proposed for the horizontal distance between a line connecting the adjacent gingival zeniths and the facial surface of the implant. A vertical distance guideline of 3.0 to 4.0 mm is proposed between the adjacent gingival zeniths and the implant platform. (J Prosthet Dent 2025;133:827-837)

Replicating the exact shape, cervical contour, and peri-implant mucosal position of adjacent natural teeth can be challenging for single implant-supported crowns. Achieving the best possible esthetic result requires ideal implant placement along with normal hard and soft tissue position and form. When implants are placed in healed sites, obtaining an ideal result is particularly difficult because of bone resorption that has typically reduced the amount of facial bone. When assessing the clinical results obtained with single implant crowns placed in healed sites, certain horizontal and vertical implant positions were observed to compromise the esthetic result because of a lack of bone and/or soft tissue; this resulted in abnormal cer-

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Clinical Implications

When the proposed horizontal and vertical implant locations cannot be obtained in healed sites, bone grafting should be considered before or in conjunction with implant placement to aid in the development of the optimal cervical crown form. An implant planning software program with incorporated 3D scan data can be used to determine whether implants can be positioned in optimal locations or whether bone grafting is needed.

vical crown or mucosal contours (Fig. 1) and/or crown height differences when compared with adjacent natural teeth (Fig. 2). In contrast, when adequate bone and soft tissue are present in healed sites, implants can be placed in horizontal and vertical positions that result in better cervical crown and mucosal contours (Fig. 3).

Ideally, the facial cervical contour of implant crowns should be in harmony with that of the adjacent teeth. However, if an implant is not ideally positioned (Fig. 4) and/or the supporting facial bone and soft tissue are compromised (Fig. 5), the cervical contour of a crown is often jeopardized.[1] Therefore, to achieve proper cervical crown contour, optimal 3-dimensional implant positioning is important. In the event bone is not available to achieve an ideal implant position, then bone grafting is recommended.[2]

For many years, clinicians have recognized the importance of horizontal and vertical implant positions on the esthetic results obtained with implant single crowns[3,4] This recognition has resulted in general horizontal guidelines, whereas both general and specific numerical vertical guidelines have been published.

Regarding horizontal guidelines, publications have mentioned the detrimental effect of placing an implant too far facially or lingually, without specific numerical guidelines relative to the adjacent teeth.[3–5] Implants placed too far facially increase the risk of mucosal recession,[4] leading to crowns with greater than normal incisocervical or occlusocervical dimension,[5] (Fig. 2) while implants positioned too far lingually result in crowns with deficient cervical prominence or require a ridge-lap design to obtain the desired facial cervical crown contour (Fig. 5). However, crowns with a ridge-lap design complicate oral hygiene access and can be unesthetic, especially in the presence of mucosal recession[5–7] when a ledge of porcelain will be visible that also collects food (Fig. 6).

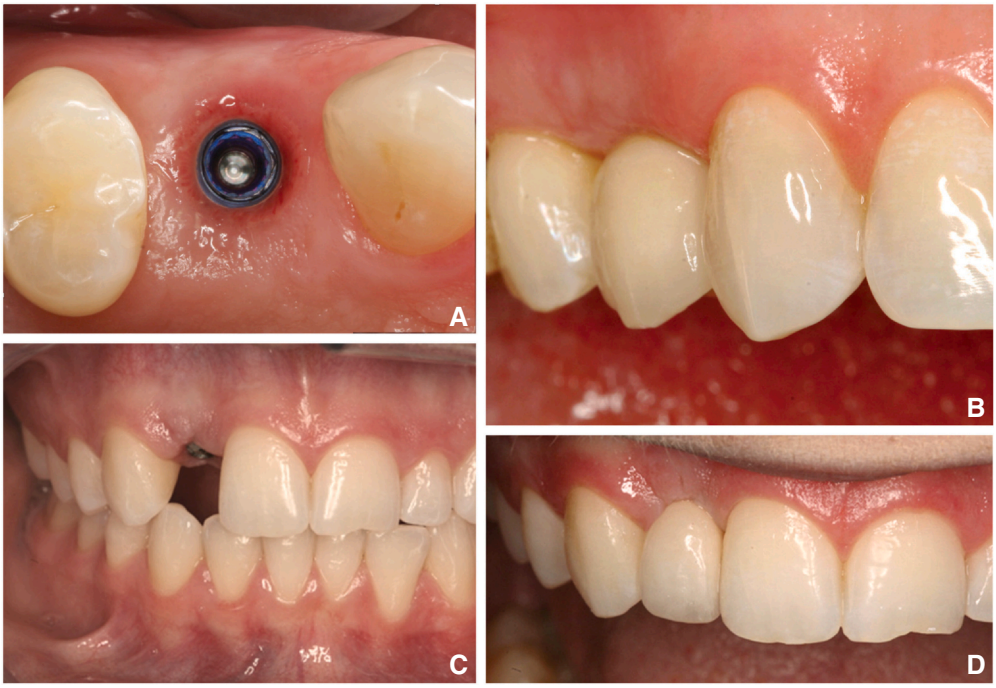

Figure 1. A, Slightly lingual implant position relative to facial surfaces of adjacent teeth. B, View of first premolar cervical crown contour with less cervical prominence compared with adjacent natural canine and second premolar due to crown curving lingually to meet implant. C, Example of maxillary lateral incisor implant too lingual due to facial bone resorption. D, Lateral incisor crown with deficient cervical crown contour due to crown angling lingually to meet lingually positioned implant.

Figure 2. A, Maxillary central incisor implant too facial, causing apical mucosa position. B, Implant crown with greater than normal incisocervical crown dimension.

Figure 3. A, Proper maxillary central incisor implant position but zirconia abutment with excessive facial prominence. Mucosal margin slightly apical relative to adjacent central incisor. B, Peri-implant mucosal zenith slightly apical to adjacent central incisor.

Both general and specific numerical guidelines have been published relative to the vertical positioning of implants. The general guidelines stated that shallow implant locations do not provide sufficient vertical space for a transition from the form of the implant to the desired crown form as it emerges from the mucosa, producing an abnormal cervical crown contour.[4] However, excessively deep implant positions can result in an suboptimal mucosal form,[5] since greater marginal bone change was noted when implants were placed apical to the marginal bone.[8]

In addition to these general guidelines, specific numerical values have been published regarding vertical implant positioning. In 2004, it was stated the implant shoulder (platform) should be placed 2.0 mm apical to the midfacial soft tissue margin of the planned crown in esthetic situations.[6] More recently, emphasis has been placed on the importance of positioning the implant further apically (3.0 to 4.0 mm) relative to the soft tissue crest.[1] In addition to apicocoronal implant depth, the type of tooth being replaced has been discussed.[5] It was recommended that 4.0 mm diameter implants placed in maxillary central incisor sites should be positioned 3.0 to 4.0 mm apical to the gingival margin of the contralateral tooth.[5] This depth will allow for a gradual transition from the diameter of the implant platform to the required dimension of the crown as it emerges from the mucosa. The authors also stated that maxillary lateral incisor implants would not need to be as deep, since the smaller crown dimension does not require as great a distance to transition from the implant to the desired emergence profile of the crown.[5]

Clinical observations and previous publications have shown that a relationship exists between horizontal and vertical implant positions and the esthetic result obtained with implant single crowns. However, numerical guidelines regarding the horizontal and vertical implant locations to help optimize cervical crown esthetics relative to adjacent teeth when single implants are placed in healed edentulous sites are lacking. Such guidelines would help determine when bone grafting is needed in healed sites to optimize cervical crown contours.

The purpose of this subjective assessment was to evaluate the cervical contour of wax patterns formed on casts where single implants had been placed into healed edentulous sites without bone grafting and to determine which horizontal and vertical implant positions produced good cervical crown contours and which locations would have required bone grafting to optimize cervical crown form. The null hypothesis was that no relationship would be found between horizontal and vertical implant positions and optimal cervical crown form.

MATERIAL AND METHODS

This investigation was reviewed by the Institutional Review Board (IRB# 5230409) and determined not to require IRB review or approval. To assess the cervical crown contour, 58 casts without any patient identifiers were obtained from the private practice of one of the authors (C.J.G.) where single implants had been placed in maxillary premolar and first molar sites without any bone grafting procedures. The implants

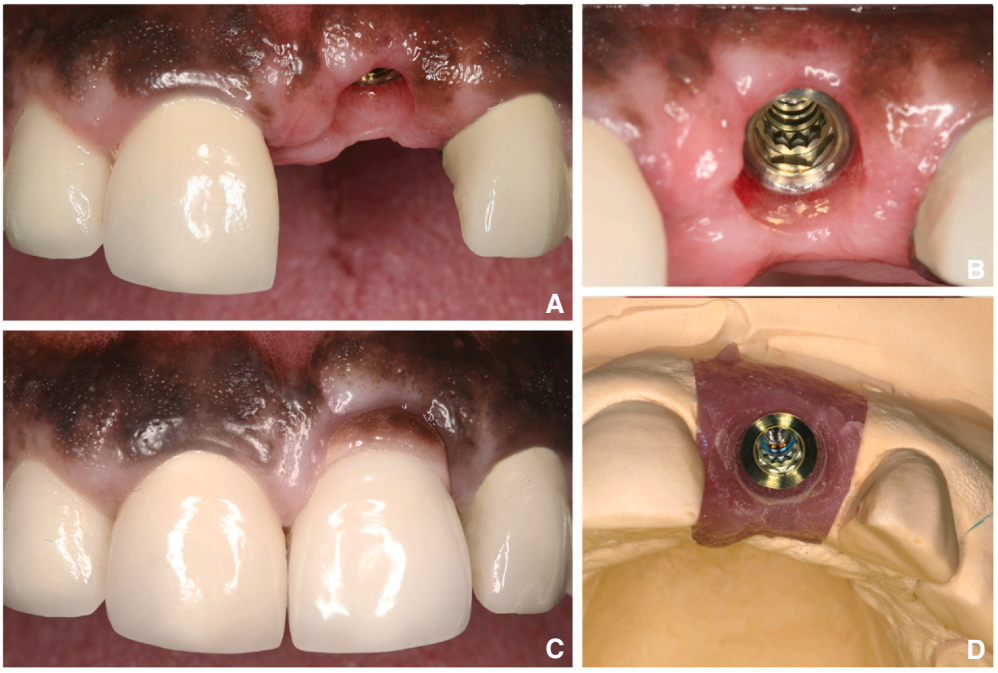

Figure 4. A, Central incisor implant too facial. B, Incisal view showing implant facial to prominence of adjacent ceramic crowns. C, Mucosal colored ceramic added to cervical aspect of crown to simulate pigmented mucosa because of facial implant position. D, Facial position of implant on definitive cast.

had been restored over a period of years, and the casts were used to evaluate the effect of implant position on the cervical crown contour. Maxillary posterior sites were selected because the cervical crown contour could be assessed using a frontal view, replicating the way posterior crowns are assessed clinically by looking down the line of teeth to see how the implant crown contour simulates that of adjacent teeth.

The single implants had been placed in 35 maxillary premolar sites and 23 maxillary first molar sites. To measure the horizontal and vertical positions of the implants in the casts, a Boley gauge and 1.5-mm-thick round metal wire were used after removing the flexible peri-implant mucosa present on the cast. The wire was positioned in contact with the gingival zeniths of the 2 adjacent natural teeth to produce a horizontal line connecting the zeniths. The horizontal distance was measured between the lingual surface of the wire and the facial surface of the implant, and then the vertical distance was measured between the inferior surface of the horizontal wire and the plane of the implant platform (Fig. 7). Each measurement was rounded to 0.1 mm.

The flexible peri-implant mucosa was then replaced onto the casts and wax patterns were formed to be as congruent as possible with the cervical contour of the adjacent natural teeth but without creating any ridge-lap over the mucosa. All the wax patterns were platform matched. The coronal portion of the wax patterns were formed using a tan colored wax, and the submucosal portions were established using gray wax. In this way, it was easier to evaluate the supramucosal and submucosal crown contours. The wax patterns were created by one of the authors (J.W.P.) and then assessed by another (C.J.G) with extensive experience in teaching tooth morphology as being properly formed given the variations in implant positions.

The wax pattern contours were compared from a frontal midline view with the natural teeth located anteriorly and posteriorly (Fig. 8). The resulting contour assessments could then be used to identify implant locations that compromised the cervical crown contours and to show where bone grafting would have been required to optimize the cervical contour. Both horizontal and vertical implant positions were measured on the casts relative to the facial gingival zeniths of adjacent natural teeth.

Five experienced faculty clinicians and 5 graduate students evaluated the wax patterns. Using a standardized frontal view of the casts (Fig. 7), each evaluator subjectively assessed the cervical contour of the

Figure 5. A, Maxillary first premolar implant substantially lingual to desirable location associated with buccal bone resorption. B, Occlusal view of crown on definitive cast with lingual location of screw access channel. Note that crown extends lingually farther than would be normal for second premolar. C, Crown with ridge lap design because of lingual implant position and need for facial extension of porcelain. D, Facial view of implant crown and adjacent natural tooth crown showing occlusocervical dimension of implant crown associated with ridge lap design. E, Frontal view of posterior teeth showing facial and cervical extension of crown required to approximate facial contour of first premolar tooth. Note increased occlusocervical crown dimension associated with ridge lap.

Figure 6. First molar implant crown with ridge lap over facial mucosa. Soft tissue recession with large space between ceramic ridge lap and mucosa, presenting oral hygiene challenge along with esthetic deficiency.

wax patterns relative to the adjacent teeth, replicating how maxillary posterior crowns would be viewed clinically to assess their crown contours relative to adjacent teeth. The evaluators ranked the cervical contour as good, fair, or poor with numerical values (3, 2, 1) assigned to each of the 3 categories. Good ratings were judged to have normal cervical contour relative to the adjacent natural teeth, fair ratings had some cervical contour deficiency, and poor ratings were due to a substantially deficient cervical crown contour (Fig. 9). Numerical values from the 10 evaluators were combined to calculate an average for each of the wax patterns. The average numbers were rounded to the nearest whole number, and each of the wax patterns was assigned to its corresponding good, fair, and poor group. The resulting mean horizontal and vertical distances of the implant from the wire were compared in relation to the subjective assessment of the cervical wax pattern contour.

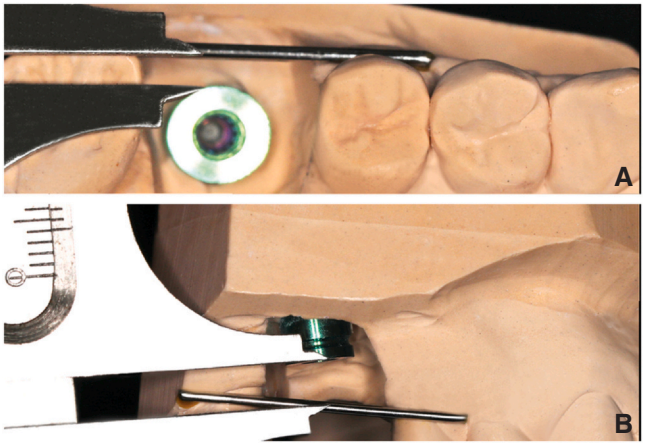

Figure 7. A, Boley gauge measuring horizontal distance from lingual aspect of round orthodontic wire to facial surface of implant. B, Boley gauge measuring vertical distance between wire and implant platform. Note wire in contact with gingival zeniths of adjacent teeth on definitive cast.

Figure 8. Frontal view of representative cast showing view used by examiners to rate cervical contour as good, fair, or poor.

RESULTS

Among the 58 implants placed into maxillary posterior healed sites (35 premolars and 23 first molars) without bone grafting, 10 crowns were determined to have good cervical contour, 34 were categorized as fair, and 14 were judged to be poor.

Horizontally, the wax patterns evaluated as good had an average distance of 2.6 mm lingual to the facially positioned wire with a range from 1.7 to 3.5 mm. For the wax patterns judged to be fair, the average horizontal distance was also 2.6 mm, but there was a greater range of 1.0 to 5.0 mm. The patterns assessed as having a poor cervical contour had a mean horizontal distance of 3.2 mm with a range of 1.4 to 4.4 mm.

Vertically, the wax patterns judged to be good had an average distance of 3.0 mm apical to the wire with a range from 2.0 to 4.5 mm. The average vertical distance of the crowns assessed as having a fair cervical contour was 2.4 mm with a range from 0.5 to 4.2 mm. The patterns assessed as having a poor cervical contour had a mean vertical distance of 0.7 mm with a range from minus 1.5, meaning the implant platform was located occlusal to the wire, to 2.0 mm (Table 1).

The poor horizontal assessments were associated with the implants either being positioned greater than 3.0 mm lingual to the wire or less than 2.0 mm lingual to the wire. Poor vertical assessments were primarily associated with the implant platforms being located 1.0 mm or less apical to the adjacent gingival margins or actually being positioned occlusal to the horizontal line, thereby producing a negative measurement.

DISCUSSION

The null hypothesis that no relationship would be found between horizontal and vertical implant positions and optimal cervical crown form was rejected. A somewhat unique aspect of this publication was the focus on implant placement in healed sites without bone grafting. This topic has not been emphasized in recent literature with the focus on immediate implant placement and associated guidelines as to where the implant should be placed horizontally and vertically relative to the extraction socket walls. As a result, clinicians may find the

Figure 9. A, Representative example of maxillary second premolar wax pattern with good cervical crown form. B, Representative example of maxillary second premolar wax pattern with fair form because of undercontoured cervical aspect of wax pattern. C, Representative example of maxillary first molar wax pattern with poor cervical crown form because of substantially undercontoured cervical area.

Table 1. Mean and range (mm) of horizontal and vertical distances of premolar and molar single implants relative to gingival zenith of adjacent teeth and resulting cervical crown form

Contours Judged as Good, Fair, or Poor					
Good		**Fair**		**Poor**	
Horizontal Distance	**Vertical Distance**	**Horizontal Distance**	**Vertical Distance**	**Horizontal Distance**	**Vertical Distance**
2.6 mm Mean Range 1.7-3.5	3.0 mm Mean Range 2.0-4.5	2.6 mm Mean Range 1.0-5.0	2.4 mm Mean Range 0.5-4.2	3.2 mm Mean Range 1.4-4.4	0.7 mm Mean Range −1.5-2.0

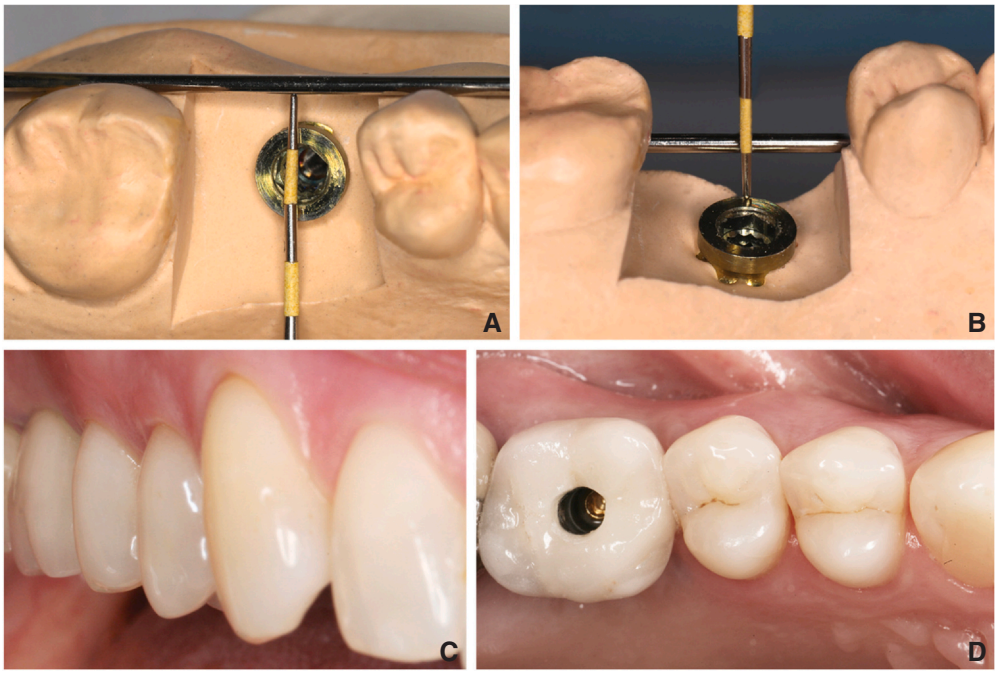

Figure 10. Example of horizontal and vertical implant positioning resulting in favorable crown and mucosal form. A, 2.0 mm distance between facial surface of maxillary first molar implant and metal wire in contact with gingival zeniths of adjacent teeth. B, 3.0 mm distance between wire and implant platform. C, Definitive crown with close approximation of mucosa around implant crown compared with mucosa on adjacent teeth associated with good implant placement. D, Occlusal view of molar implant crown after tightening abutment screw but before restoring occlusal screw access channel.

guidelines proposed in this paper for horizontal and vertical implant placement helpful in treatment planning implant placement in healed sites and determining when bone grafting is needed to optimize the result.

Clinical experience indicates it is easier to obtain an optimal crown shape and mucosal relationship to the crown when a tooth is extracted and an implant immediately placed into the extraction socket as opposed to placing an implant in a healed site where some bone resorption has occurred. Because of the difficulty in obtaining ideal implant placement in healed sites, wax patterns were made on casts where implants had been placed in healed sites without any bone grafting to obtain the subjective perspective of clinicians regarding the effect of the implant position on the cervical wax pattern contour. Then, the locations of the implants were measured to help determine horizontal and vertical implant positions that resulted in compromised cervical crown contours and where bone grafting would have been required to optimize the cervical crown contour. Based on the number of wax patterns subjectively judged to have a good cervical crown contour in this assessment (10 of 58), most healed sites will require bone grafting for an optimal result.

Since the implants were placed into a variety of healed ridges, the implants were not always centered

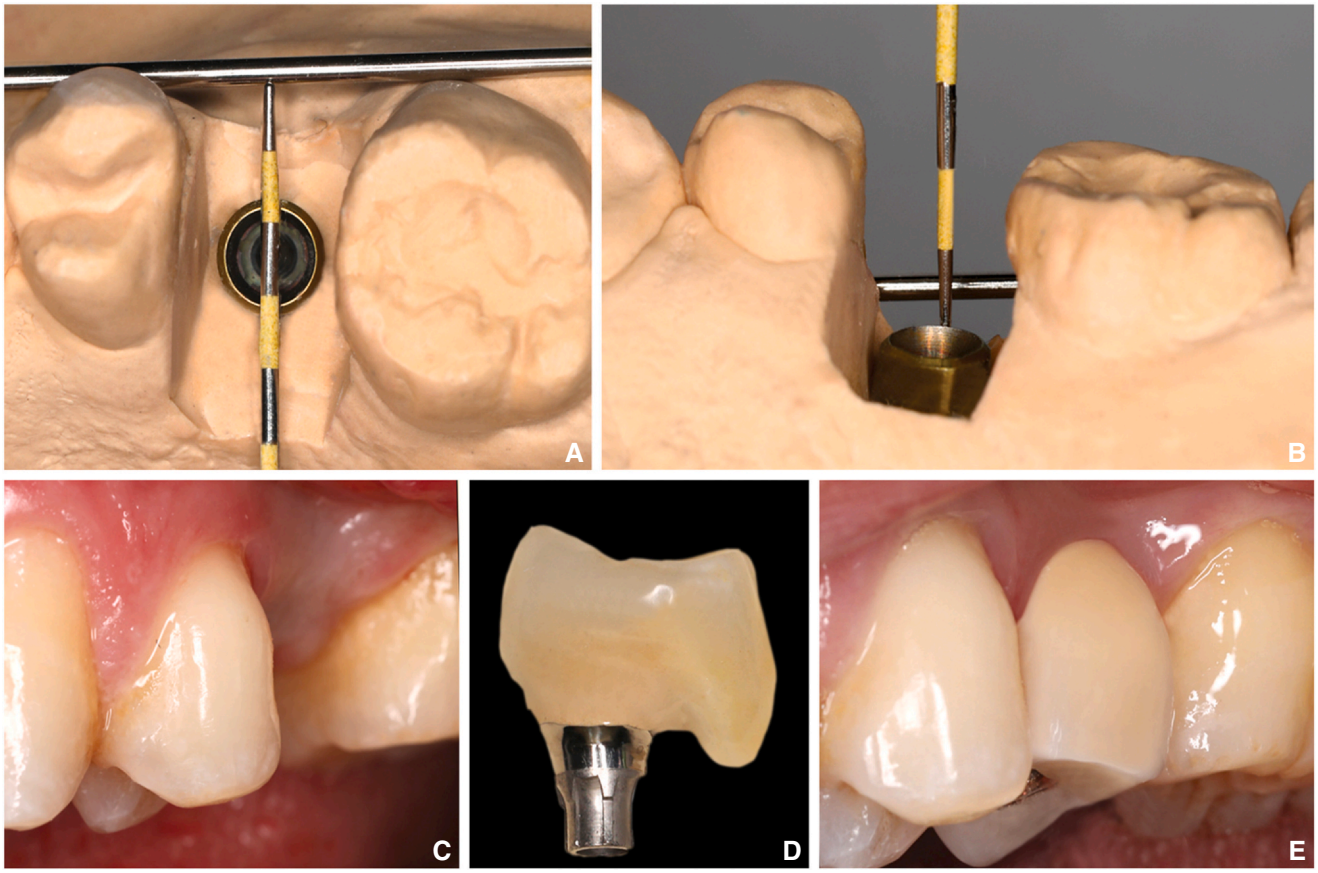

Figure 11. A, Maxillary second premolar implant 5.0 mm lingual to metal wire because of amount of facial bone resorption. B, Implant only 1.0 mm apical to metal wire, shallower than optimal. C, Clinical view showing amount of facial bone resorption before implant placement. D, Image showing effect of lingual implant placement and need for ceramic ridge lap. E, Clinical view of crown showing crown with difficult oral hygiene access to facial mucosa and implant surface.

beneath the occlusal surface of the crown and the biomechanics may not have been ideal; however, the focus of this assessment was to determine the effect on cervical crown contour and not on biomechanics. A future study could evaluate the effect of implant positioning in healed sites on crown biomechanics.

Clinical photographs of the single implant crowns were available for most of the evaluated casts. These photographs supported the results of the subjective assessment of the cervical wax pattern form and correlated with the horizontal and vertical distances as recorded on the casts. For instance, when the horizontal and vertical guidelines were within the proposed recommendations, the esthetic results appeared appropriate (Fig. 10) versus less-than-ideal implant locations that compromised the esthetic result or resulted in the need for a ridge lap design (Fig. 11).

When implants were horizontally located too far lingually relative to the adjacent gingival margins, substantially deficient cervical contours resulted, or a ridge-lap design would have been needed to form more desirable cervical crown contours. Ridge lap designs should be avoided because they compromise oral hygiene (Fig. 5) and produce supragingival ledges of porcelain should mucosal recession occur (Fig. 6). Implants placed too far facially resulted in crowns with a greater than normal occlusocervical dimension because of mucosal recession (Fig. 2).

The mean vertical implant location data indicate that implants placed 3.0 mm apical to a horizontal line connecting the adjacent gingival margins resulted in cervical crown forms judged to be good, whereas a mean vertical distance of 2.4 mm was judged to be fair and a mean vertical distance of 0.7 mm resulted in a poor assessment

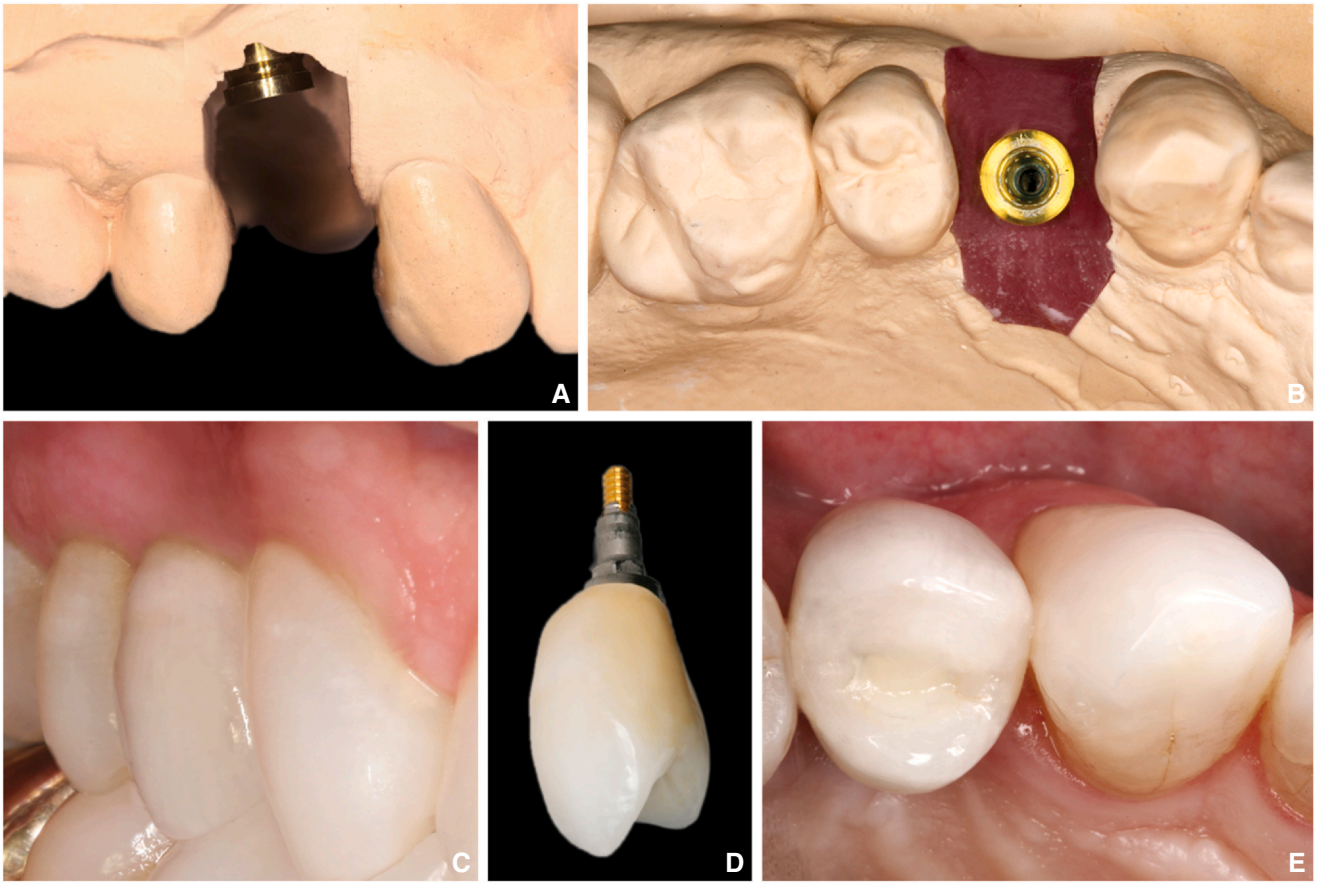

Figure 12. A, Maxillary first premolar implant deeper than recommended. B, Implant also further lingual than optimal. C, View showing acceptable facial cervical contour associated with deeper implant position and gradual increase in facial surface prominence until crown emerged from mucosa. D, Crown on bench showing lingually positioned implant and tall crown with greater vertical distance available to gradually increase facial surface prominence. E, Occlusal view of crown showing lingual position of composite resin in occlusal screw access channel.

of the cervical crown contour. The range of poor cervical crown form assessments was from vertical distances of negative 1.5 (implant platform above the adjacent gingival zeniths) to 2.0 mm, indicating that shallow positions are more likely to result in poor crown form compared with deeper positions. When there is limited vertical distance to transition from the implant form to that of a normal cervical tooth form, placing implants in shallower vertical positions makes it difficult to establish a harmonious cervical contour with adjacent teeth.

The purpose of this publication was not to imply that the proposed horizontal and vertical guidelines are the only way of obtaining good cervical contours. There are many factors involved, such as vertical implant position and facial bone thickness, which affect where an implant can be positioned horizontally, and mucosal thickness, which can affect the apical mucosal location after implant placement. Some less than optimal implant positions such as a lingually positioned implant can still result in an appropriate cervical crown contour when the vertical position is sufficiently deep that it allows for a gradual increase in the prominence of the cervical crown form as it emerges from the mucosa (Fig. 12). This observation supports the important interaction between the vertical and horizontal implant locations and how they can affect each other. Therefore, both the horizontal and vertical implant positions can work together to produce an appropriate cervical emergence profile.

To determine whether bone grafting is needed to avoid a compromised cervical crown contour, an implant planning software program with incorporated 3-dimensional scan data should be used to locate single implant positions in existing edentulous ridges. The horizontal and vertical distances of the proposed sites

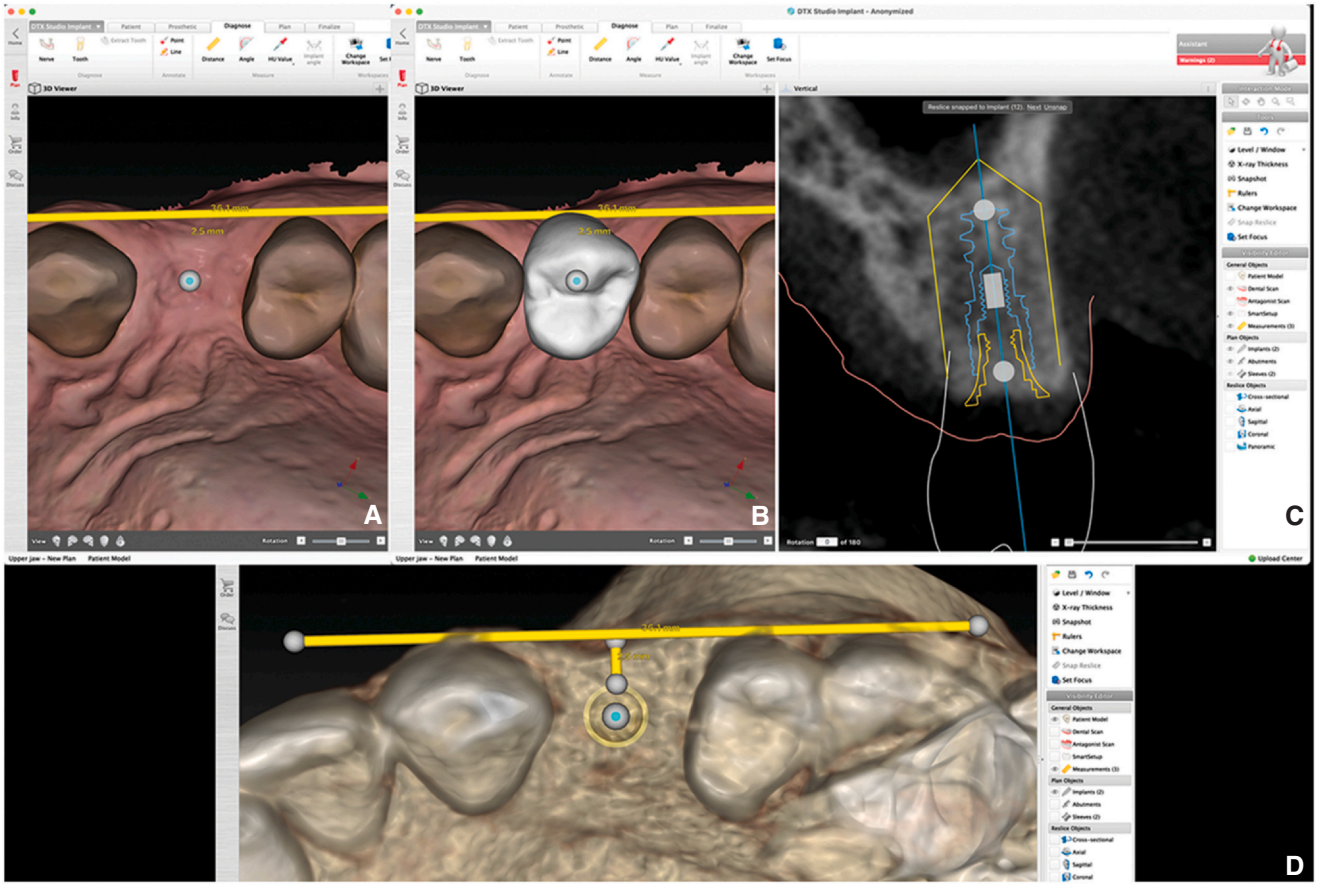

Figure 13. A, Software program simulating optimal implant location within bone. *Yellow line* on gingival zeniths of adjacent teeth. *Circle* represents center of implant. B, Virtual crown and implant location. C, Virtual implant position and angulation. D, Bone and implant without soft tissue. Facial implant surface relative to *yellow line* and effect of distance on cervical crown contour and need for bone grafting.

relative to a line connecting the adjacent gingival margins should then be measured (Fig. 13). In this way, whether it will be possible to meet the proposed guidelines and obtain a desirable cervical crown contour or whether bone grafting is needed can be determined.

Limitations of the study included the subjective nature of the wax pattern assessment. In addition, the perspective of only 10 clinicians was included. An assessment by a larger number of clinicians may have produced different dimensional results. Also, the examination of a larger number of casts could have produced different results. Similar assessments should be made by other groups of clinicians to determine the effect of implant location on cervical crown form when implants are placed in healed sites.

CONCLUSIONS

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

1. A guideline of 2.0 to 3.0 mm is proposed for the horizontal distance between a line connecting the gingival zeniths of adjacent teeth and the facial surface of a single implant. This proposal is based on 2.6 mm being the average horizontal distance for wax patterns judged to have a good cervical crown contour. Distances greater than 3.0 mm resulted in contours determined to be deficient. Also, distances less than 2.0 mm resulted in crowns with a greater than desirable incisocervical/occlusocervical dimension due to the facial mucosa being located farther apically.
2. A vertical distance of 3.0 to 4.0 mm between a line connecting the adjacent gingival zeniths and the implant platform is proposed as a guideline, since 3.0 mm was the average distance that produced wax patterns judged to have good contour, whereas shallower positions in fair or poor contour assessments.
3. When planning the location of single implants in healed sites and when the vertical and horizontal distances in relation to the gingival zeniths of adjacent teeth will not meet the guidelines proposed above, then bone grafting is recommended to obtain optimal cervical crown contours.

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