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Alveolar ridge width and height changes after orthodontic space opening in patients congenitally missing maxillary lateral incisors

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SUMMARY The purpose of this study was to evaluate the dimensional changes of the alveolar ridge in patients with congenitally missing maxillary lateral incisors. The width and height of the alveolar ridge were compared before and after opening space for an endosseous dental implant between the central incisor and canine. Pre- and post-treatment dental stone models of 31 patients (8 males, 23 females; mean age 15.1 ± 7.9 years pre-treatment, 17.6 ± 8 years post-treatment) with unilaterally or bilaterally, congenitally missing maxillary lateral incisors were used in this study. Pre- and post-treatment measurements included: the space between the maxillary central incisor and canine, the depth of the labial concavity, and the width and height of the lateral incisor alveolar ridge. Two different techniques were used to measure the ridge width. Student's paired samples *t*-test was used to test for significance. The alveolar ridge underwent statistically significant width loss (Method 1: 4–8 per cent, Method 2: 13–15 per cent) during the course of orthodontic treatment. A 6–12 per cent loss in ridge height was also noted. The depth of the labial concavity between the maxillary central incisor and canine nearly doubled. There was a significant decrease in the width and height of the alveolar ridge in patients congenitally missing a maxillary lateral incisor who received orthodontic treatment to create space for an endosseous dental implant.

Introduction

The orthodontic management of congenitally missing maxillary lateral incisors has three common treatment approaches: space closure by means of canine substitution, the placement of an endosseous dental implant, and a tooth supported restoration. Replacement of the missing teeth with an endosseous dental implant is a viable option, especially when adjacent teeth are healthy and unrestored (Kokich, 2004). An alveolar ridge with adequate dimensions is a prerequisite for an ideally restored endosseous dental implant in the anterior aesthetic zone. When the height and width of the edentulous ridge is inadequate, grafting procedures may be necessary.

It has been suggested that the orthodontic movement of adjacent teeth through the edentulous alveolar ridge can develop adequate alveolar ridge dimensions without resorting to grafting procedures (Zachrisson, 2003; Gunduz *et al.*, 2004; Kokich, 2004). Bone is deposited as the teeth move along the ridge, reconstituting any dimensional deficiencies. According to Kokich, if a permanent lateral incisor is congenitally absent, it may be advisable to allow the permanent canine to erupt mesially into the lateral incisor space. The canine can then be orthodontically moved distally to develop a site with proper dimensions able to receive an implant without a graft (Kokich, 1994, 2004; Spear *et al.*, 1997). However, a study by Beyer *et al.* (2007) produced results that conflicted with Kokich's findings. They found a significant decrease in ridge volume from 0.26 mm^2 at the beginning of orthodontic treatment to 1.92 mm^2 at the end of orthodontic treatment.

Research studies have primarily focused on evaluating the alveolar bone dimensional stability many years after ridge development, however, information on the immediate ridge dimensional changes after the canine distalization is lacking. Furthermore, no study has quantified the labial concavity of the ridge in the lateral incisor area when the canine is distalized after erupting in close proximity to the central incisor.

The objective of this retrospective study was to evaluate the dimensional changes of the alveolar ridge in patients with congenitally missing maxillary lateral incisors by comparing the width and height of the ridge before and after space is created for an implant between the central incisor and canine. This will help determine whether there is sufficient bone for proper implant placement without having to resort to bone grafting procedures. The null hypothesis assumed that there would be no significant reduction in the alveolar ridge dimensions after space is opened for a congenitally missing maxillary lateral incisor to fit an endosseous dental implant.

Materials and methods

Data were obtained from 31 sets of dental stone models of patients from the orthodontic clinic at the University of Connecticut and from a private practice of an alumn. Cases were selected using the inclusion/exclusion criteria described in Table 1. Twenty-one patients had bilaterally missing maxillary lateral incisors and 10 patients had a unilaterally missing maxillary lateral incisor. One of the sites was excluded in patients with bilateral agenesis if the inclusion criteria were not met (seven patients). A total of 45 sites were evaluated. The mean ages of the patients (8 males, 23 females) were 15.1 ± 7.9 years pre-treatment and 17.6 ± 8 years post-treatment. Total mean orthodontic treatment time was 2.5 ± 0.9 years. All measurements on the stone models were taken using a Boley gauge (Swiss Precision, Garden Grove, USA) and measured to the tenth of a millimetre. The space between the maxillary central incisor and canine was measured in pre- and post-treatment models. From an occlusal perspective, the depth of the labial ridge concavity between the maxillary central incisor and canine was measured. The measurement was taken from the deepest part of the concavity to a line tangent to the gingival prominences of the maxillary central incisor and canine (Figure 1a).

The bucco-lingual ridge width was measured using two different techniques (Figure 1b). The first method was based on the technique described by Stepovich (1979). Briefly, the most incisal point at the middle of the soft tissue ridge (buccolingually and mesiodistally), between the maxillary central incisor and canine, was located by inspection. From this point, two points 4 mm down the slope of the ridge, one labially and one lingually, were located. The width of ridge was measured between these two points. For the second method, the gingival margin of the maxillary central incisor was used as a reference point. A labial point was located 2.5 mm apical to the gingival margin of the central incisor. From this point, a line parallel to the occlusal plane was drawn towards the canine. The same reference method was used on the lingual side. Several defined points along the labial and lingual lines were located and used to measure the width of the ridge. The pre-treatment and post-treatment model had three measurements: 1. middle of the central incisor, 2. middle of the canine, and 3. between the central incisor and canine (at the contact point if they were in contact or at the middle of the ridge if they were not in contact).

Alveolar ridge height was measured using the method described by Hom (Hom and Turley, 1984). In this method, the maxillary occlusal plane was used as a reference line (Figure 1c). Measurements were taken from this line to the: 1. mesial alveolar soft tissue crest (distal to central incisor), 2. middle of the ridge, and 3. distal alveolar soft tissue crest (mesial to canine).

The protocol was reviewed and approved by the Institutional Review Board at the University of Connecticut (IRB# 10-113-3).

Table 1 Inclusion/exclusion criteria for the selection of cases.

Inclusion criteria
1 Unilateral or bilateral congenitally missing maxillary lateral incisors.
2 Permanent canine erupted mesially into the lateral space and adjacent to the central incisor.
3 Space between the distal surface of the central incisor and the mesial surface of the canine less than or equal to 2 mm.
4 Canine orthodontically distalized to create space for an implant.
Exclusion criteria
1 Primary lateral incisor present and the permanent canine erupted distal to the lateral incisor.
2 Impacted permanent canine is impacted or not yet fully erupted.
3 Patients with cleft palate or any other dentofacial deformities.

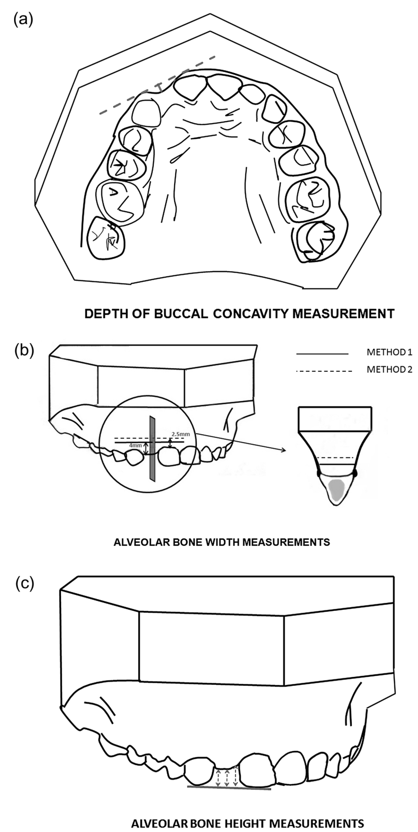

Figure 1 Methods used to measure (a) buccal concavity; (b) bone width; (c) bone height.

Statistical analysis

Statistical analyses were performed with Statistical Package for Social Sciences (version 17.0, SPSS, Chicago, Illinois, USA). The mean pre- and post-treatment measurements were calculated for each of the 31 sets of dental models. A Student's paired samples *t*-test was used to test for significance. A significance level of $P < 0.05$ was used. Although there were a total of 45 sites of analysis (14 models had bilaterally missing lateral incisors included in the study), the sites within the same models were determined to be independent from each other. Thus, two sets of analyses were conducted. Set 1 used measurements from the right side of the 14 models with bilateral missing lateral incisors, along with the measurements from the six models with either unilateral agenesis or bilateral agenesis with only one lateral incisor site meeting the inclusion criteria ($n = 20$). Set 2 used measurements from the left side of the 14 models with bilateral missing lateral incisors and used the same measurements from the 11 models with either unilateral agenesis or bilateral agenesis with only one lateral incisor meeting the inclusion criteria ($n = 25$). The two sets were then compared to each other to see if there were any major differences. Finally, the alveolar width of 10 patients with a unilateral missing lateral incisor was compared to the contralateral lateral incisor present using Method 2. This served as a control to evaluate width ridge changes with treatment on a site with and without the lateral incisor.

To test for measurement error and reliability, 10 models were randomly selected and remeasured (at least 1 week later) by the same individual (intra-examiner) and by another individual (inter-examiner). The measurement error was calculated using the formula:

$$\mathrm{ME} = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between double measurements and n is the number of pairs of measurements.

Results

The intra-examiner measurement error did not exceed ±0.15 mm, and the inter-examiner measurement error did not exceed ±0.31 mm. Measurement errors were assessed statistically using a paired samples t-test. No significant differences in intra- and inter-examiner measurements were found at either pre- or post-treatment ($P > 0.05$).

The intra-/inter-examiner correlation coefficient (ICC) was also used to test the reliability of measurements. The intra-examiner ICC values ranged from 0.96 to 0.99 (0.98 ± 0.02). The inter-examiner ICC values ranged from 0.78 to 0.99 (0.93 ± 0.06). ICC values were assessed statistically and were all found to be highly significant ($P < 0.001$).

Table 2 reports the means, standard deviations, and significance for Set 1 (right-side data). The results indicate that the space between the maxillary central incisor and canine significantly increased by 4.9 mm ($P < 0.001$), which is to be expected given the treatment protocol. A significant increase in the depth of the labial concavity was noted (0.6 mm, $P < 0.001$). No labial concavity was noticed in patients with a control maxillary lateral incisor. The width of the ridge significantly decreased in both methods of measurement (Method 1: −0.3 mm, $P < 0.05$; Method 2: −1.4 mm, $P < 0.001$). An increase in ridge width at the canine was also found (0.3 mm, $P = 0.03$). Figure 2 depicts a graphical representation of the results obtained using Method 2. The increased distance from the middle of the ridge to the maxillary occlusal plane (0.6 mm, $P < 0.05$) represents a significant decrease in ridge height. These findings indicate that there is significant change in alveolar ridge width and height.

Table 3 reports the means, standard deviations, and significance for Set 2 (left-side data). The pattern of findings from this analysis is consistent with those reported from the Set 1 analysis. There is a significant increase in space between the maxillary central incisor and canine, as expected (5.1 mm, $P < 0.001$). A significant increase in the depth of the labial concavity was noted (0.5 mm, $P < 0.001$). No labial concavity was noticed in patients with a control maxillary lateral incisor. The width of the ridge significantly decreased in both methods of measurement (Method 1: −0.6 mm, $P < 0.001$; Method 2: −1.2 mm, $P < 0.001$). An increase in ridge width at the canine was also observed (0.4 mm, $P = 0.01$). The increased distance from the middle of the ridge to the maxillary occlusal plane (0.3 mm, $P < 0.05$) represents a significant decrease in ridge height.

Ten patients with unilateral missing incisors were compared to the contralateral present lateral incisor. The width of the side with the lateral incisor did not show any significant alveolar ridge change with treatment measured using Method 2

Table 2 Set 1 (right-side data). Means (mm), standard deviations (mm), range (mm), and significance for difference between pre- and post-treatment measurements ($n = 20$).

		Pre-treatment				Post-treatment					
		Mean	SD	Max.	Min.	Mean	SD	Max.	Min.	Difference	P
Space between incisor and canine		1	0.6	2	0	5.8	0.5	6.6	4.9	4.8	<0.001***
Depth of labial concavity		0.6	0.3	1.5	0	1.1	0.3	1.8	0.6	0.5	<0.001***
Method 1 width		7	0.5	7.7	6.1	6.7	0.3	7.7	5.9	−0.3	0.008**
	Incisor	10.1	0.6	11.8	9.1	10.1	0.7	11.7	9.2	0	0.57
Method 2 width	Middle ridge	9.5	0.6	10.6	8.5	8.1	0.8	9.5	5.6	−1.4	<0.001***
	Canine	10.6	0.8	13.5	9.7	10.9	0.9	13.4	9.6	0.3	0.03**
Height	Mesial crest	4.5	0.7	5.9	2.9	4.8	0.6	6.3	3.7	0.3	0.07
	Middle crest	4.5	0.7	5.9	3.2	5.1	0.6	6.2	4.2	0.6	0.005**
	Distal crest	4.5	0.7	5	3.2	4.9	0.7	6.5	4	0.4	0.027*

$*P \leq 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.

(Table 4). Method 2 was used since Method 1 required the presence of an edentulous ridge. When the post-treatment alveolar ridge of the site with the congenitally missing incisor was compared to the contralateral normal lateral incisor, there was a significant difference in alveolar ridge width (Table 4).

Discussion

Restoring an edentulous area with an endosseous dental implant is a viable treatment option for patients with congenitally missing lateral incisors. However, a sufficient amount of bone is a definite prerequisite to ensure the placement of the dental implant in an optimal position (Kokich, 1994; Kokich and Spear, 1997; Zachrisson, 2003).

Alveolar ridge resorption is evident after tooth extraction (Carlson, 1967; Tallgren *et al.*, 1986; Ostler and Kokich, 1994). The presence of a tooth with a healthy attachment apparatus is necessary for the maintenance of alveolar bone width and height. Patients congenitally missing teeth have thin and reduced alveolar ridges since bone development in the area is hindered by the absence of a tooth. It has been reported that teeth moved through the alveolar bone are capable of restoring the lost alveolar dimensions. Moreover, Kokich reported that alveolar bone changes in patients congenitally missing lateral incisors appear to be minimal in the long term after the orthodontic movement of the canine through the edentulous ridge (Kokich, 1994). The results of this study emphasized that the long-term ridge changes after the canine was distalized; however, no data was reported regarding the ridge dimensions attained immediately after orthodontic treatment. Thus, the long-term bone preservation effects although encouraging, become secondary if the ridge dimensions are significantly diminished after space opening.

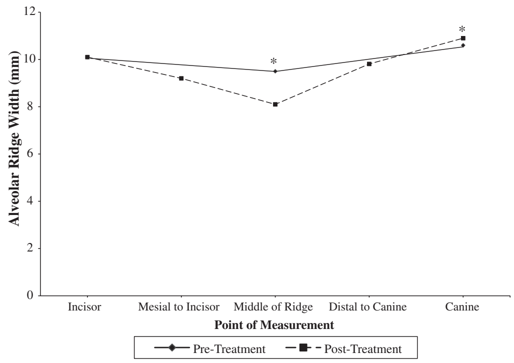

Figure 2 Pre- and post-treatment alveolar ridge width using Method 2 (*$P \leq 0.05$).

Table 3 Set 2 (left-side data). Means (mm), standard deviations (mm), range (mm), and significance for difference between pre- and post-treatment measurements (*n* = 25).

		Pre-treatment				Post-treatment					
		Mean	SD	Max.	Min.	Mean	SD	Max.	Min.	Difference	*P*
Space between incisor and canine		0.8	0.6	1.7	0	5.9	0.4	6.6	5.1	5.1	<0.001***
Depth of labial concavity		0.5	0.4	1.6	0	1	0.4	1.6	0	0.5	<0.001***
Method 1 width		7.2	0.5	8.3	6.2	6.6	0.5	7.5	6	−0.6	<0.001***
	Incisor	10	0.4	10.7	9.1	9.9	0.5	10.7	9.1	−0.1	0.46
Method 2 width	Middle ridge	9.5	0.8	11.4	8.4	8.3	1	10.4	5.7	−1.2	<0.001***
	Canine	10.4	0.7	12.3	9.1	10.8	0.8	11.9	9.3	0.4	0.01**
	Mesial crest	4.6	0.7	6.1	3.1	4.7	0.6	6.3	4	0.1	0.36
Height	Middle crest	4.6	0.7	6.1	3.6	4.9	0.6	6.5	4.1	0.3	0.02*
	Distal crest	4.6	0.7	5.8	3.1	4.6	0.6	6	3.6	0	0.62

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

Table 4 Changes in alveolar ridge width in the control versus agenesis sites in patients with unilateral agenesis (*n* = 10) using method 2.

	Pre-treatment				Post-treatment					
	Mean (mm)	SD (mm)	Max. (mm)	Min. (mm)	Mean (mm)	SD (mm)	Max.	Min.	Difference (mm)	*P*
Alveolar ridge width control side (middle lateral incisor)	9.5	0.7	10.6	8.7	9.8	0.6	10.7	9.2	0.3	0.19
Post-treatment alveolar ridge (middle)										
Control					9.8	0.6	10.7	9.2	1.4	0.0001***
Agenesis					8.4	0.8	10	7.6		

***$P \leq 0.001$.

Few studies have attempted to measure the immediate ridge dimension changes after canine distalization (Beyer *et al.*, 2007; Novackova *et al.*, 2011). Beyer evaluated stone casts of 14 patients at: 1. beginning of orthodontic treatment, 2. end of orthodontic treatment, and 3. at the time of implant placement. A predetermined dental implant size was used to measure the change in the surface area of the ridge at these three time points. Results showed an increase of ridge volume deficiency from 0.26 mm^2 at the beginning of orthodontic treatment to 1.92 mm^2 at the end of orthodontic treatment. However, two major shortcomings were evident in this study: the subjectivity in the method used to analyse ridge-volume deficiency and failure to report the amount space between the canine and the central incisor before orthodontic treatment, a very important factor when evaluating the effects of ridge development.

In a similar study, Novackova evaluated the immediate ridge width and height changes after canine distalization in stone models (Novackova *et al.*, 2011). They found a 4 per cent ridge width decrease with this procedure at two different heights of the edentulous alveolar ridge. This is consistent with our findings using Method 1; however, our results showed a more significant width ridge decrease using Method 2. The disparity in the results may be attributed to the different ridge levels used to record the linear measurements. The more incisal measurement in their study was more coronal than the one used in our study. These differences suggest a more complex three dimensional change in the ridge morphology that may be difficult to quantify with linear measurements (Figure 3b).

This study described measurable ridge height and width dimension changes at two different levels of the alveolar ridge developed by canine distalization. Furthermore, this study only included patients, in whom the canine had erupted less than 2 mm distal to the central incisor, ensuring a true ridge development with the canine movement.

The selection of a constant reference point throughout the study to evaluate the changes in alveolar ridge dimensions over time was a challenge. In our study, we explored different techniques to measure the bucco-lingual ridge width. Stepovich (1979) described using the middle of the alveolar ridge as a reference point. The problem with this method is that the position of the reference point can change over time and is therefore not a constant point. We introduced a new method that used the gingival margin of the maxillary central incisor as a reference point. Although, the gingival margin is also another volatile landmark, significant changes are not expected with treatment. From an aesthetic point of view, the gingival margin of the central incisor should be slightly higher than that of the lateral incisor (approximately 0.5 mm). Based on the biological width concept (Gargiulo *et al.*, 1961), the crest of the alveolar bone at the central incisor is about 3 mm apical to its gingival margin. Therefore, the supposed alveolar bone crest of the lateral incisor would be 2.5 mm apical to the gingival margin of the central incisor. The points of measurement of this new method appeared to be a few millimetres more gingival to the points used by Stepovich and thus increased alveolar ridge width thickness were reported with this method.

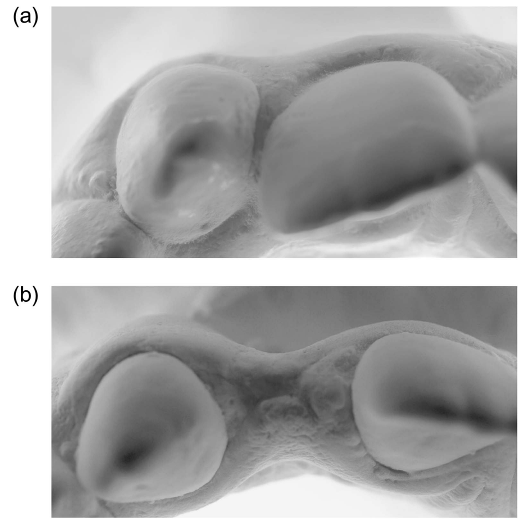

Figure 3 Clinical example of alveolar ridge changes: (a) before orthodontic space opening; (b) after orthodontic space opening.

The results of the study showed that when using the middle of ridge as a reference point, a 4–8 per cent decrease in the ridge width was seen (4 per cent for the right side and 8 per cent for the left side). When using the new method to measure the alveolar ridge, a 13–15 per cent decrease in ridge width was noted after orthodontic treatment (Figure 3). In addition to the loss of the ridge width, a 6–12 per cent loss of the ridge height was found. Finally, when the newly developed ridge in those patients with unilateral agenesis was compared to the contralateral control incisor using Method 2, the ridge was found to be significantly smaller (14 per cent), which correlates with the average width ridge change found for all sites.

The changes in ridge width are more evident with the second measuring method. The most likely explanation for this discrepancy is the stability of the reference points for measurement. In Stepovich's method, ridge width changes are measured from the crest of the soft tissue ridge, which this study showed to move gingivally after canine distalization. Thus, when the second measurement was taken, the width was measured at a more gingival level, where the ridge is wider, reflecting a smaller width change. Our new method used the gingival margin as a more stable reference point and thus may reflect more accurately the alveolar ridge width changes.

An unexpected finding was the slight increase in the ridge width at the canine level. Since the canine was distalized during treatment, the pre- and post-treatment measurements were taken at different positions along the dental arch. This could explain the discrepancy in our results. Also, during the course of treatment, the canine may have rotated or changed in root inclination causing a slightly greater expansion in the ridge width.

Although the changes in alveolar width and height were significant, it can be considered that height changes are more important than width changes when a dental implant is to be placed. Alveolar ridge dimension changes can be addressed with grafting procedures more predictably in width than in height (Tonetti and Hammerle, 2008); therefore, a clinically significant height change may contraindicate the placement of an implant. Fortunately, the height dimension changes were not clinically significant to impair aesthetics in the event of implant placement. This can be corroborated with the finding that the post-treatment ridge height did not exceed 6 mm.

Perhaps, the most important clinical finding was the increase in ridge concavity with space opening. No study has quantified the magnitude of this ridge change. Although the labial ridge concavity only increased by half a millimeter at the end of treatment, the concavity nearly doubled its original depth, being on average 1 mm. This concavity may impair the positioning of the implant during surgery and result in possible unaesthetic consequences of implant translucency due to reduced or absent labial bone. Furthermore, the presence of adequate labial bone is not only important in the short term it may also prevent any further bone loss in the future (Leblebicioglu *et al.*, 2007).

Although the average post-treatment alveolar bone width measured with Method 2 was adequate for the placement of a conventional 5.5 mm wide implant, great variability was found. Considering the minimum range value of 5.6 mm, it should be highlighted that some patients may be unable to receive an implant without bone grafting. Moreover, the absolute width dimension may be secondary to the degree of labial ridge resorption; therefore, although the alveolar width may be adequate, ideal implant placement may be hindered by a lingually displaced ridge.

In our study, we measured the alveolar ridge on dental models. The ridge consists of both hard and soft tissue. We were not able to determine the exact decrease in bone due to the nature of the study. However, we were successful in visualizing and quantifying a trend in patients undergoing this type of procedure regardless of the measuring method, i.e. the narrowing of the alveolar ridge. A study using cone beam computed tomography to assess the dimensional changes in the alveolar bone would be the next step in solidifying our results. In addition, it would be of interest to follow these patients long term to evaluate how frequently bone grafting was required at the time of implant placement. Finally, a control group in which the canine was minimally distalized, or not distalized at all, would evaluate whether the clinical recommendation of promoting the mesial eruption of the canine and subsequent distalization is worthwhile.

Conclusions

The results of this study show a significant decrease in alveolar ridge width and height immediately after orthodontic space opening for congenitally missing maxillary lateral incisors. The presence of a labial concavity between the central incisor and canine is evidence of this alveolar ridge loss. Although distal movement of the canine may develop the alveolar ridge in patients congenitally missing lateral incisors, the bone width may not be sufficient for ideal placement of an endossesous implant without grafting.

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