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Assessment of the permanent canine bone support after secondary bone graft in UCLP patients

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The purpose of this retrospective study was to evaluate the level of alveolar bone support of the erupted permanent canine through the reconstructed cleft region compared to the contralateral canine on the non-cleft side.

This study was limited to children with complete unilateral cleft lip and palate who underwent secondary alveolar iliac bone graft and the apices of the erupted canine roots were closed at the time of evaluation. With these criteria the study included 21 children whose average age at the time of bone graft reconstruction was 9.8 years, with a minimum of 12.4 years of age at the time of the evaluation.

The study was limited to the use of iliac cancellous bone as the autograft material for reconstruction of the alveolar cleft. Cranial bone graft and other autogenous bone sources were excluded.

The periapical radiographs were used to evaluate alveolar bone level of each canine. The percentages of root supported by the bone were established by dividing the amount of root covered with the bone by the anatomic root length. The canine of the non-cleft side was used as an internal control and the canine on the cleft side was used as an experimental.

There was a statistically significant difference in the alveolar bone support ratio between the control (92.9%) and experimental canines (88.7%). An average of 95% level of alveolar bone support was achieved for the experimental canine in comparison to the control canine. Neither the presence of lateral incisor, nor the stage of root development of the canine at the time of the bone graft appeared to have affected the alveolar bone support ratio of the canine after the secondary bone graft.

Key words : Cleft lip/palate, Alveolar bone graft, Bone graft success

Cleft lip and/or palate (CL/P) malformations are considered one of the most common abnormalities in the craniofacial region. In the staged reconstruction of these anatomic deformities, dental considerations are an important part of the overall treatment plan. From the orthodontist's perspective, a primary concern is restoring the maxillary arch continuity and alignment of the dentition. The typically collapsed arch form is orthodontically expanded, the maxillary alveolar cleft is then surgically reconstructed with the bone graft, and any soft tissue fistulas are closed. The alveolar bone grafts are performed in the osseous defective cleft region to provide a more ideal environment for the erupting dentition adjacent to the cleft, most frequently, the permanent canine. Even if the tooth follicle is present, the tooth will not typically erupt without the presence of the overlying bone. Thus alveolar bone graft reconstruction is essential in the management of cleft deformities, preventing maxillary segmental collapse, establishing a favorable osseous environment for dental eruption and tooth support, closing of alveolar orolabial-nasal fistula, and providing alar-base support for nasal symmetry. While the

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Table 1. Study Sample Description.

Case No.	Type*	Sex	Age at Graft	Age at Evaluation	Root Development of Canine&	Presence of Lateral Incisor#
1	UCLP/L	M	7.5	18.9	2	A
2	CPPL/R	M	7.1	12.5	1	P
3	UCLP/L	M	12.5	15.9	4	A
4	UCLP/L	F	10.5	13.5	1	A
5	UCLP/R	M	12.8	14.4	3	A
6	UCLP/L	F	8.3	14.6	-	A
7	UCLP/R	M	14.9	15.5	6	P
8	CPP/L, BU	F	6.5	14.9	1	A
9	UCLP/R	M	7.4	15.0	2	A
10	UCLP/R	M	12.8	14.9	5	A
11	UCLP/L	M	7.5	14.0	2	A
12	UCLP/L	M	6.1	12.4	1	A
13	CPP/L, CSP	M	11.5	15.0	4	A
14	UCLP/L	M	9.3	13.8	3	P
15	CLA/L	F	6.3	13.5	1	A
16	UCLP/L	M	-	14.5	-	A
17	CPP/L, CSP	F	10.7	15.7	4	A
18	UCLP/L	M	15.9	19.0	6	A
19	UCLP/L	M	10.2	13.9	4	A
20	ICLA/R	M	12.3	13.6	4	P
21	ICLA/L	F	6.0	13.6	3	P
Average			9.8	14.7		

*CPPL/R : Cleft primary palate and lip/Right
CPP/L, BU : Cleft primary palate/Left, Bifid uvula
CPP/L, CSP : Cleft of Secondary palate, Left primary palate
CLA/L : Cleft Lip and Alveolus/Left
ICLA/R : Incomplete cleft lip and alveolus/Right
ICLA/L : Incomplete cleft lip and alveolus/Left
#Presence of lateral incisor : A absent, P present
&Root developmental stage is shown in Table 2.
- Unidentifiable

timing of alveolar bone graft is debated, these surgical objectives are well accepted.

The success of the alveolar bone graft can thus be judged on various criteria depending on the surgical objective. From an orthodontic and dental standpoint the level of bony support to the canine provided by the reconstruction would be a critical measure of success.

The degree of alveolar bone support within the cleft region has been assessed by a number of investigators.[1,2,3] These methods range from subjective descriptions to objective measurement of the grafted alveolar bone level. Success typically has been measured against the normative data in the general population : However, the multitude of factors that can account

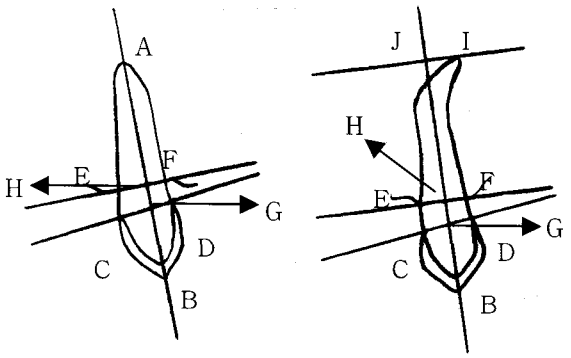

Figure 1. Determination of pertinent dental structures and long axis
G : intersection between the long axis and the line from mesial CEJ to distal CEJ
H : intersection between the long axis and the line from mesial alveolar bone height to the distal alveolar bone height

for the individual variations is not easy to control and comparison may not be possible with the general population. If, instead, it is assumed that the alveolar bone support of the canine on the non-cleft side represents the maximum amount of bone that could be achieved for the canine on the cleft side in a particular individual, then the canine on the non-cleft side may provide for an internal control and is a more relevant comparison. Then the following hypothesis can be proposed : There should be no difference in alveolar bone level between the alveolar bone grafted canine and non-grafted canine on the opposite side under ideal circumstances. With this hypothesis, two primary questions initiated this retrospective study.

· How much alveolar bone support can be achieved for the permanent canine erupting into the cleft site after a secondary bone graft?

· What factors affect the alveolar bone support of the permanent canine after the secondary bone graft?

MATERIALS AND METHODS

Study Sample

One hundred fifty five patients with complete unilateral cleft lip and palate who underwent secondary bone graft procedures using autogenous cancellous bone from iliac crest from 1990 to 1997 at Chicago Shriners Hospitals for Children were evaluated. The management of each patient was planned and monitored by the Northwestern University Cleft Palate Institute. The orthodontic treatment was performed either by the Orthodontic Department at Northwestern University or by private orthodontists. Twenty-one patients (6 Females, 15 Males) were selected by the selection criteria described below :

1) Patients should have complete unilateral cleft lip and palate involving alveolar cleft.
2) Patients should have maxillary permanent canines fully erupted on both sides at the time of assessment.
3) Both maxillary permanent canines should have closed apices at the time of assessment.

The average age at the time of bone grafting was 9 years 9 months with a range of 6 years to 14 years 10 months. The average length of post-surgical follow-up was 4 years 10 months. Table 1 summarizes the specifics of the patient population used in this study.

Determination of alveolar bone support of the canine

Periapical radiographs were taken for the permanent canine on both sides by the standardized long cone paralleling technique. The permanent canine erupted on the cleft side was designated as the experimental canine, while the contralateral canine of the non-cleft side was designated as the control canine.

Pertinent dental structures were identified on each periapical radiograph and traced onto acetate paper. All tracings were completed by two different examiners in order to assess reliability. A paired t-test was performed for the values of alveolar bone support ratio from the two examiners if there was a reliable agreement between the two examiners.

The percentage of alveolar bone support of the permanent canine was calculated using the following method. (Figure 1)

The long axis of the tooth was constructed between root apex and crown tip. (A-B)

1) An intersecting line connecting mesial and distal cementoenamel junctions was constructed. (C-D)
2) Root length was estimated as the distance between root apex and the intersection of the tooth long axis line and cementoenamel junction line. (A-G)
3) A line connecting alveolar crests mesial and distal to the tooth was constructed. (E-F)

The height of alveolar bone support was estimated as the distance between root apex and the intersection of the tooth long axis line and alveolar crests line. (A-H)

Alveolar Bone Support Ratio(%) was calculated using the following formula :

$$\frac{\text{Height of Alveolar Bone Support(AH)}}{\text{Root Length(AG)}} \times 100$$

If the permanent canine had a curved root, several modifications were made to determine the long axis and root length.

1) The long axis was constructed by drawing a line along the middle of the root canal.
2) A perpendicular line was constructed from the most apical point (I) of the root to the long axis and the intersecting point was designated as J.
3) Root length was estimated as the distance from J to the intersection of the tooth long axis line and cementoenamel junction line. (J-G)

Alveolar Bone Support Ratio(%) was calculated using the following formula :

$$\frac{\text{Height of Alveolar Bone Support(JH)}}{\text{Root Length(JG)}} \times 100$$

%-Achieved

Alveolar bone support ratio of the experimental canine was compared to that of the control canine in each sample. The relative amount of bone support achieved for the experimental canine was designated as %-Achieved. %-Achieved(%) was calculated using the following formula :

$$\frac{\text{Alveolar Bone Support Ratio of the Experimental canine}}{\text{Alveolar Bone Support Ratio of the Control canine}} \times 100$$

Table 2. Stages of root development of the canine

Stage	Root development of the canine
0	Crown complete, no root
1	Initial root formation (spicule of root)
2	Root 1/4 length(Root length less than crown)
3	Root 1/2 length(Root length equal to crown)
4	Root 3/4 length(Root length more than crown)
5	Root length complete (termination point open)
6	Completed root formation (apex closed)

Absolute Value vs Relative Value

Two different values were calculated for the alveolar bone support ratio. Alveolar bone support ratios at the control and experimental side were used as absolute values and the %-Achieved ratios were used as relative values.

Independent Variables

1. Age at the time of bone grafting

Chronological age at the time of bone grafting was tested to determine if a correlation existed with the alveolar bone support ratio of the experimental canine (absolute value) or to the %-Achieved (relative value) after the secondary bone graft.

2. Stages of Canine Development at the time of bone grafting

The stages of root development of the canine at the cleft site was tested to determine if there was a correlation to the alveolar bone support ratio of the experimental canine (absolute value) or to the %-Achieved (relative value) after the secondary bone graft.

Table 3. Average - Alveolar Bone Support Ratio (%) & %-Achieved

Case Number	Control (%)	Experimental (%)	% Achieved
1	89.4	87.1	97.5
2	95.2	96.3	101.2
3	97.5	95.4	92.3
4	91.7	81.8	89.2
5	97.8	95.4	97.6
6	88.7	86.2	97.2
7	88.2	88.1	99.9
8	94.0	74.2	79.0
9	90.3	88.6	98.1
10	93.5	93.8	100.4
11	94.1	92.6	98.4
12	89.6	84.6	94.5
13	85.7	81.2	94.7
14	96.7	94.3	97.6
15	95.0	84.5	88.9
16	94.7	89.9	95.0
17	92.5	87.6	94.7
18	91.1	88.4	97.0
19	94.6	90.9	96.1
20	93.8	87.8	93.7
21	97.3	94.8	97.4
Average	92.9±3.35	88.7±5.58	95.3±4.92

Criteria for determining the stages of Permanent Canine Root Development

For this evaluation, extra-oral radiographs (orthopantomograph), which had been taken within 6 months from the date of bone graft, was utilized. Permanent canine root development at the time of bone graft was evaluated using the criteria used by El Deeb et al.[4] (Table 2)

3. Presence of Lateral incisor at the cleft site

The presence or congenital absence of the lateral incisor at the cleft site at the time of the bone grafting was evaluated to test for any statistically significant difference in the alveolar bone support ratio of the experimental canine (absolute value) or for the %-Achieved (relative value) after the secondary bone graft.

4. Type of Eruption of the canine

Naturally-erupted or orthodontically-erupted canines were divided into two groups. These two groups were evaluated to test for any statistically significant difference in the alveolar bone support ratio of the experimental canine (absolute value) or for the %-Achieved (relative value) after the secondary bone graft.

Statistical Treatment of the Data

The average value between the two examiners was used for the alveolar bone support ratio of the control and experimental canines and for the %-Achieved since the values from the two different examiners showed no statistically significant difference.

Student's t-test for paired data was used to compare the alveolar bone support ratio of the experimental and control canines.

Student's t-test for unpaired data was used to compare the presence or absence of the lateral incisor at the cleft site for the alveolar bone support ratio of the experimental canines and %-Achieved.

Linear regression analysis was tested to find if there was any significant correlation between patient's age at the time of surgery and %-Achieved or alveolar bone support ratio of the experimental canine. The same statistical method was used to test for any correlation between the stages of canine root development and %-Achieved or alveolar bone support ratio of the experimental canine.

The data was examined for statistical significance at a probability level of 0.05.

RESULTS

The average alveolar bone support ratio of the control and experimental canine and average %-Achieved are shown in Table 3.

Student's t-test for paired sample demonstrated a statistically significant difference in the alveolar bone support ratio between the control and the experimental canines. An average of 95% of alveolar bone support of the control canines was achieved for the experimental canines after the secondary bone graft.

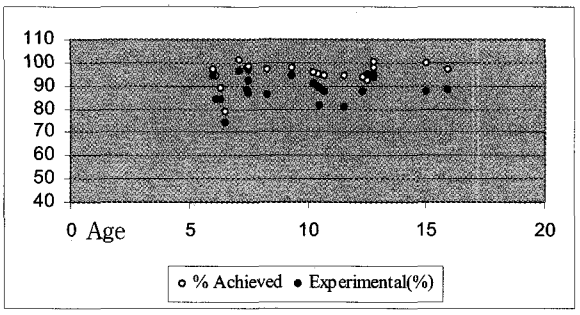

Figure 2. Correlation between the age at the time of bone grafting and absolute or relative bone support of the canine at the experimental side

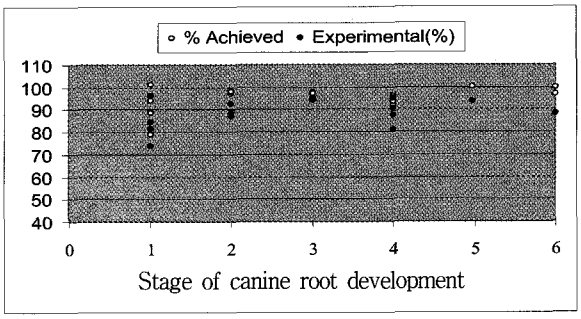

Figure 3. Correlation between the stages of canine root development and absolute or relative bone support of the canine at the experimental side

1. Age at the time of bone graft

Linear regression statistics demonstrated that age at the time of bone grafting had no significant effect on the alveolar bone support ratio of the experimental canines (P=0.439) nor on the relative value, %-Achieved (P=0.292). (Figure 2)

2. Stages of canine development at the time of bone graft

Linear regression statistics demonstrated that the different stages of canine root development had no significant effect on the alveolar bone support ratio of the experimental canine (P=0.248), or on the relative value, %-Achieved (P=0.082). (Figure 3)

3. Presence of Lateral Incisor at the cleft site

Sixteen out of twenty-one samples showed an absence of lateral incisor while only five samples had the lateral incisor present at the cleft site at the time of bone grafting.

Average %-Achieved for the lateral incisor present group was 93.8 ± 8.68%, while the lateral incisor absent group was 95.7 ± 3.34%. Alveolar bone support ratio of the experimental canine was 89.5 ± 9.14% for the lateral incisor present group and 88.1 ± 3.97% for the lateral incisor absent group. Student's t-test showed that there was no significant difference in the alveolar bone support ratio of the experimental canine (P=0.619), or in the relative value, %-Achieved (P=0.456), whether a lateral incisor was present or congenitally missing. (Figure 4)

4. Type of Eruption

There were only three samples that had permanent canines surgically exposed and erupted orthodontically. Statistical evaluation could not be performed because the sample sizes were too small. Average %-Achieved for the orthodontically-erupted group was 96.8 ± 2.04% and for the naturally-erupted group was 95.0 ± 5.24 %. Alveolar bone support ratio of the experimental canine was 88.1 ± 4.07% for the orthodontically-erupted group and 88.4 ± 5.66% for the naturally-erupted group. The average value did not show much difference between the two groups.

DISCUSSION

In a child born with a facial cleft, reconstructing the maxillary alveolar cleft deformity with bone grafting procedures promotes the eruption of the permanent canine through the cleft site and provides for its long-term stability. This stability, provided by the new bone, is important for subsequent orthodontic alignment and final dental rehabilitation.

There have been a number of studies in the literature that have assessed the level of bone support in the region of the erupted canine after a secondary

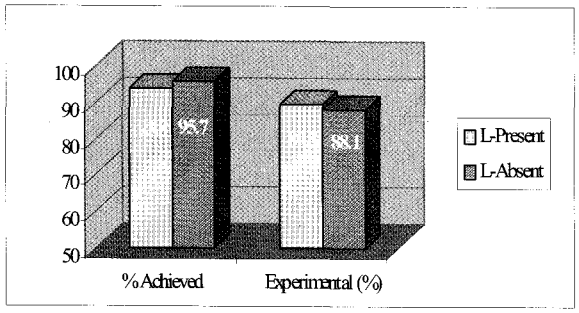

Figure 4. %-Achieved and Alveolar bone support ratio of the experimental canine

bone graft. These studies have utilized two-dimensional periapical radiographs to assess the amount of bone surrounding the erupted canine. Films for comparative purposes should be standardized, however controlling the angulation of the radiographic cone is not easily accomplished, as the palatal vault is shallow in cleft patients. Duinkerke et al[5] suggested that the use of a relative measurement instead of an absolute measure of the alveolar crest height and root length would control the magnification. In a well-designed study, Albandar et al[6] evaluated various techniques to assess the change in the alveolar bone level. The techniques included : 1. an absolute method which measures the distance from the alveolar bone to a reference point : 2. a relative method which transforms the alveolar bone height to a fraction of the radiographic root length and : 3. a relative method employing the radiographic tooth length instead of the root length. Of these, they found that the second technique was the most reliable for detecting the radiographic change in the bone level. For this reason the ratio of the alveolar bone height to the canine root length-the alveolar bone support ratio-was chosen for this study as a measure of the alveolar bone support.

To assess the success of the bone graft reconstruction, previous studies compared the measurements with normative data available in a standard population. The level of bone support depends ultimately not only on the specifics of the surgical intervention but also on the individual genetic and environmental factors. To control for this individual variability, the level of bone support of the erupted canine on the non-cleft side was chosen as a more relevant control than the general norm. Comparison of the alveolar bone support ratio on each side then allowed the measurement of the percentage achieved on the reconstructed cleft side.

When to evaluate the outcome of the bone graft reconstruction is important. The timing of assessment has varied in previously published studies.[7,8] Age range of the samples at follow-up was 9.7-21.8 years in the study by Long et al[7] and 8.2-16.1 years in the study by Rosenstein et al.[8] It can be assumed that a clinically more relevant and consistent assessment of the level of the bone support should be made when the apex of the maxillary canine root is closed. In general, the maxillary canine root apex is closed when the child is beyond 12 to 13 years of age. For this study, 155 patients with complete unilateral cleft lip and palate were evaluated who underwent secondary iliac alveolar bone graft reconstruction from 1990 through 1997. With these inclusion criteria, the study was then limited to 21 patients with identified closed root apex whose ages ranged from 12.5 to 19 years.

For this subset, the alveolar bone support ratio of the canine on the cleft and on the non-cleft side was first calculated and then compared, as a percentage achieved based on the alveolar bone support of the non-cleft canine. The level of bone support of the canine on the cleft side was found to have an average of 88.7%. This is comparable to a previous study by Long et al[3] that showed an average of 87% of the alveolar bone support of canine on the cleft side. However, on the non-cleft side, the level of bone support of the canine was found to be 92.9%, a statistically significant difference. If the level of bone support of the non-cleft canine is the achievable maximum within that individual, the level of bone support of the canine through the reconstructed cleft site then had an average of 95.3%, that is, the %-Achieved of the level of bone support of the non-cleft canine.

A range of 88-100% of alveolar bone support ratio can be considered normal in a general population if 0-2mm range of the distance from the cementoenamel junction to the alveolar bone level is considered normal. This study suggests then that the normal range of

alveolar bone support was achieved for the canine with a secondary bone graft. However, the alveolar bone support ratio of the experimental canine was significantly lower than that of the control canine within the same individual even though an average of 95% of alveolar bone support of the control side was achieved. This suggests that the normal range of alveolar bone support in the age group of this study should be considered higher than that of the general population.

Bergland et al[9] stated that the functional element which determines the complete formation and maintenance of the interdental septum might be related to a close approximation of the teeth. They also stated that if the distance between the teeth on either side of the cleft was too large, the alveolar bone graft would not maintain its original level.[9] The study by Dummer et al[10] showed that the loss of the adjacent tooth appears to have a significant effect on the alveolar bone height. However, in this study, the presence of the lateral incisor did not significantly affect the level of alveolar bone support for the canine in the cleft area.

The timing of the secondary alveolar bone grafting has been an issue for many years. Chronological or dental age as well as the development or position of the teeth in the cleft site, usually the permanent canine, has been mentioned as one of the factors, which can affect the outcome of secondary bone graft. El Deeb et al[4] found that when the root of the permanent canine was one-fourth to one-half developed, successful eruption of the canine through grafts occurred. They also stated that the age range of 9-12 years had an excellent prognosis for tooth eruption.[4] Hall and Posnick[11] stated that the optimal age for the operation is approximately 8 to 10 years. At this time period of development the canine root is about half developed and growth of the maxilla would not be expected to be retarded by the surgery since growth in the area of the alveolar cleft is nearly completed by 8 years of age. Bergland et al[9] recommended that bone grafts should be done prior to full canine eruption. Enemark et al[2] insisted that the potential problem of external root resorption caused by iliac crest cancellous bone could be avoided if the bone grafting was performed before eruption of the canine. But Long et al[3] found no significant relationships between the degree of canine eruption and ultimate bone graft success. In this study, canine eruption status could not be used as an independent variable since periapical radiographs were not available to verify the degree of canine eruption at the time of the bone graft. But the stage of root development was verifiable with occlusal and panoramic films, and this could be used as an independent variable to be tested for this study. Because two out of twenty one samples did not have appropriate records to determine the stage of canine root development, only nineteen samples were tested for this purpose. Linear regression analysis showed that the chronological age or the stage of root development of the canine did not significantly affect on the absolute or relative measurement of alveolar bone support of the canine. This study supports the findings of the recent study by Long et al.[3]

In this study, 86% of the samples showed spontaneous eruption of the canine, and three out of twenty one patients required surgical exposure and orthodontic eruption of the canine. This result was comparable to previous studies[1,2,9], which showed 97%, 92%, 85%, respectively. But in the study by El Deeb et al[4], 17% of the canines in the cleft-side were surgically exposed and 56% were surgically exposed and erupted orthodontically. With their preference for earlier surgical intervention and orthodontic assistance, their results would underestimate the number of unassisted eruption that might have occurred. Since the sample size of this study was not large enough to test the difference between the spontaneously erupted group and surgical -orthodontic erupted group, statistical evaluation could not be performed. However, the average values in absolute and in relative value of alveolar bone support did not appear to show an obvious difference.

SUMMARY AND CONCLUSIONS

This retrospective study was undertaken to assess the level of alveolar bone support of the erupted permanent canine through the reconstructed alveolar cleft with iliac bone graft. The alveolar bone support was determined as a relative ratio of the alveolar bone height to the length of the permanent canine root. The

degree of alveolar bone support of the canine on the cleft side was then compared to the level of bone support of the canine on the non-cleft side. This was measured as the %-Achieved. Various factors-the chronological age, the stage of root development, presence of a lateral incisor and type of canine eruption were examined to see what effect they may have on the level of canine alveolar bone support. In summary the following conclusions are significant :

· There was less alveolar bone support of the canine on the cleft side (88.7%) than the canine on the non-cleft side (92.9%). This was statistically significant.
· An average of 95.3% of non-cleft side alveolar bone support was achieved on the cleft-side canine with secondary iliac alveolar bone graft cleft reconstruction.
· Neither chronological age nor the stage of canine development at the time of grafting influenced the level of alveolar bone support achieved.
· There was no difference in alveolar bone support achieved for the canine after secondary bone graft whether the lateral incisor is congenitally missing or present in the cleft side.

There are many factors that may have the potential to influence the ultimate outcome, and this study is limited by its sample size. Long-term prospective study with a larger sample size may reveal better surgical criteria to be considered for ideal surgical outcome.

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국문초록

편측성 순구개열 환자에서 이차 골이식후 맹출된 영구 견치의 치조골 지지도에 관한 연구

성균관대학교 의과대학 삼성서울병원 치과진료부 교정과

박 기 태

치조골 파열을 동반한 순구개열 환자의 대부분은 영구견치 상방의 치조골 결손으로 인하여 맹출장애를 일으키게 되는데 이차적인 치조골이식을 통하여 영구견치의 맹출을 유도하게 된다.

본 연구의 목적은 순구개열 환자에서 재건된 치조골을 통하여 맹출된 영구견치의 치조골 지지도(alveolar bone support)를 정상 치조골을 통하여 맹출한 영구견치의 치조골 지지도(alveolar bone support)와 비교 평가하고 치조골 파열에 인접한 측절치의 유무 또는 치조골 이식수술시의 견치의 치근발육 정도가 수술후 견치의 치조골 지지도에 미치는 영향에 대하여 알아보는 것이다.

본 연구는 편측성 구개열 환자중 장골을 이용하여 이차적인 치조골 이식수술을 받은 21명의 아동을 대상으로 하였고 치조골 이식수술 당시의 평균 연령은 9.8세 였으며 치조골 지지도 평가시의 최소 연령은 12.4세 였다.

치조골 지지도의 평가를 위하여 치근단 방사선 사진을 이용하였으며 해부학적 치근 길이에 대한 치조골로 지지된 치근단 길이를 백분율로 환산하여 치조골 지지도로 계산하였다. 동일한 환자에 있어서 치조골 파열부위의 견치를 실험군으로 정상부위의 견치를 대조군으로 사용하여 실험군의 대조군에 대한 치조골 지지도 획득 비율을 계산하였다.

실험군 견치의 치조골 지지도(88.7%)와 대조군 견치의 치조골 지지도(92.9%)사이에는 통계학 적으로 유의한 차이가 있었으며 실험군 견치에서는 대조군 견치의 평균 95%에 해당하는 치조골 지지도를 보였다. 치조골 파열 부위의 측절치의 존재여부와 치조골 이식당시의 환자의 나이 또는 영구견치의 치근 발육정도는 영구견치의 치조골 지지도에 유의할 만한 차이를 만들지는 않았다.

주요 단어 : 순구개열, 치조골 이식술, 골이식 성공률