Original Article

Crown-root ratio of permanent teeth in cleft lip and palate patients

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ABSTRACT

Objectives: To determine root lengths of fully developed permanent teeth of cleft lip and palate (CLP) patients and to define their crown-root (C/R) ratios.

Method: Crown height and root length of permanent teeth were measured from panoramic radiographs of 44 CLP patients and 37 controls. A total of 1397 teeth were measured, and C/R ratios were calculated.

Results: Higher C/R ratios were found in CLP patients; this was statistically significant for both maxillary and mandibular incisors and canines. Bilateral CLP subjects showed higher C/R ratios in general than unilateral CLP subjects. Roots of maxillary incisors, canines, and some other teeth were significantly shorter in CLP patients than in controls.

Conclusions: CLP patients should be considered to have unfavorable C/R ratios, which could be the result of short root lengths for some teeth. (*Angle Orthod.* 2010;80:1122–1128.)

KEY WORDS: Crown height; Crown-root ratio; Root length; Panoramic; Cleft lip and palate

INTRODUCTION

Cleft lip and palate (CLP) account for a large fraction of all human birth defects and are notable for their significant life-long morbidity and complex etiology. CLP is not just a localized, transient disruption in development, in that patients with CLP have considerably more dental anomalies than do individuals without clefts.[1–3] Common findings include reduced size of crowns and roots (altered crown-root ratio), aberrant root forms, simplified crown morphology, and malformed teeth.[4,5] Systemic, compromised growth potential in these patients is expressed as decreased tooth size and amplified asymmetry, both of which affect all the teeth in both arches.[5] On the other hand, the cleft itself is at least partially responsible for the observed reduction in growth potential.[4]

An increased incidence of morphologic dental crown abnormalities associated with various expressions of CLP has been reported by several investigators; these abnormalities have affected both upper and lower arches and both anterior and posterior teeth.[1,5–8] Similarly, several studies have been carried out to assess root development in cleft patients; however, most of these focused on root development of the lateral incisor in the vicinity of the cleft.[9–11] Unlike bony structures, teeth do not remodel, so transient insults will be recorded in those teeth undergoing morphogenesis at that time, and chronic debilitations will affect multiple teeth.

The morphologic events associated with tooth root formation in a variety of animals have been thoroughly described; however, the mechanisms involved in human tooth root formation are not well understood.[12,13] Some types of environmental insults during tooth development were found to result in short-rooted teeth; these include chemotherapy[14] and radiation therapy.[15] Short roots also have been observed in some disorders such as scleroderma,[16] Stevens-Johnson syndrome,[17] Down syndrome,[18] and Turner syndrome.[19,20] Short roots, resulting in high unfavorable crown-root (C/R) ratios, may affect the prognosis of teeth, especially in patients with chronic periodontitis, and may complicate orthodontic or prosthodontic treatment planning. The main reasons for short dental roots are disturbances during dental root development and resorption of originally well-developed roots.[21]

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Table 1. Total Sample[a]

	Controls	CLP		Total
		BCLP	UCLP	
Male	17	8	15	40
Female	20	9	12	41
Total	37	17	27	81

[a] CLP indicates cleft lip and palate; BCLP, bilateral cleft lip and palate; and UCLP, unilateral cleft lip and palate.

A more extreme condition known as short root anomaly has been described by some authors.[22,23] In this condition, the short roots are not due to resorption, nor are they due to any systemic disturbance associated with generalized shortness of the roots. The roots in this condition have been described as developmentally very short, blunt roots of the maxillary incisor teeth.[23]

Underexplored topics regarding CLP subjects include tooth root length and C/R ratio. We could find no reports that compare the C/R ratios in CLP patients with those in healthy patients with fully developed dentitions. Therefore the aims of this study are (1) to define C/R ratios, and (2) to determine the root lengths of fully developed permanent teeth of CLP patients and healthy Jordanian controls. This information could be valuable for clinical application during orthodontic or prosthodontic treatment.

MATERIALS AND METHODS

Information for the present investigation was obtained from cleft palate patients' records at the Oral and Maxillofacial Surgery Outpatient Clinic at King Abdullah University Hospital, and from orthodontic patients' records at the Dental Teaching Center at Jordan University of Science and Technology. Subjects were included if they met the following criteria: (1) had a diagnosis of unilateral CLP (UCLP) or bilateral CLP (BCLP) with no other recognizable syndromes, (2) were older than 12 years of age (when most permanent tooth roots are completed, excluding third molars), and (3) had a clear panoramic radiograph. The study sample consisted of 44 CLP patients ranging in age from 12 to 31 years (mean, 18.5 $\pm$ 3.6 years) and 37 age- and sex-matched controls who were selected randomly from patient records in the orthodontic department. Ages of controls ranged from 12 to 30 years (mean, 19.3 $\pm$ 2.2 years). The distribution of the sample is summarized in Table 1.

Measurements

Under ideal conditions, including the use of subdued lights, film masking, a magnifying lens, and a conventional viewing box, the outlines of the permanent maxillary and mandibular teeth were apparent. The outlines of these teeth were marked with a special pencil. Crown heights and root lengths were measured using the method of Lind, which was adapted for use in posterior teeth,[23] and measurements were made with a sliding digital caliber on acetate sheets (Mitutoyo, Tokyo, Japan). All measurements were rounded to the nearest tenth decimal.

For the purposes of tooth length measurements, three parallel reference lines were drawn. An incisal/occlusal reference line formed a tangent to an incisal tip or a buccal cusp and was visually placed perpendicular to the long axis of the tooth. The cervical reference line was the line joining the mesial and distal cervical margins of enamel. The apical reference line touched the outermost part of the root, and in teeth with two buccal roots, the longer root was measured; this line was visually placed perpendicular to the long axis of the tooth.[23] The palatal roots of the maxillary molars were omitted. Crown height was the perpendicular line from the midpoint of the cervical reference line to the incisal/occlusal reference line. Root length was the perpendicular line from the midpoint of the cervical reference line to the apical reference line. The C/R ratio of an individual tooth was calculated by dividing crown height by root length.

Individual teeth were excluded if (1) teeth showed obvious distortion, (2) the apex was not closed, (3) root resorption was evident, (4) the teeth were impacted, or (5) marked attrition or abrasion of the crown was noted.

To assess intraexaminer reproducibility and the reliability of measurements, 300 teeth on 13 panoramic radiographs were remeasured at a minimum interval of 2 months.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS), version 15.0 (SPSS Inc, Chicago, Ill), was used for statistical analysis. Mean values for C/R ratios of CLP and control subjects were calculated. Differences in mean C/R ratios between CLP subjects and controls, BCLP and UCLP, CLP males and females, control males and females, and cleft side and noncleft side of UCLP patients, in addition to differences in mean crown and root lengths in CLP subjects, were studied using independent sample *t*-tests.

The precision of the measurement was calculated by means of the method of error (ME), according to the following formula:

$$ME = \sqrt{d2/2n},$$

where d is the difference between duplicate measurements, and n is the number of duplicate measurements.[24]

Table 2. Differences in Mean C/R Ratios Between UCLP and Control, BCLP and Control[a]

Tooth		N	Mean C/R Ratio ± Standard Deviation	*P* Value
11, 21	Control	59	0.519 ± 0.065	
	BCLP	13	0.614 ± 0.15	**
	UCLP	32	0.564 ± 0.061	**
12, 22	Control	53	0.488 ± 0.069	
	BCLP	12	0.577 ± 0.121	**
	UCLP	12	0.544 ± 0.077	*
13, 23	Control	57	0.486 ± 0.062	
	BCLP	10	0.563 ± 0.123	**
	UCLP	25	0.511 ± 0.084	NS
14, 24	Control	40	0.524 ± 0.074	
	BCLP	8	0.589 ± 0.093	*
	UCLP	21	0.539 ± 0.075	NS
15, 25	Control	54	0.517 ± 0.086	
	BCLP	9	0.493 ± 0.046	NS
	UCLP	19	0.492 ± 0.065	NS
16, 26	Control	62	0.610 ± 0.088	
	BCLP	25	0.602 ± 0.08	NS
	UCLP	33	0.613 ± 0.106	NS
17, 27	Control	52	0.548 ± 0.076	
	BCLP	12	0.623 ± 0.068	**
	UCLP	23	0.564 ± 0.084	NS
31, 41	Control	61	0.510 ± 0.076	
	BCLP	22	0.651 ± 0.125	***
	UCLP	45	0.564 ± 0.08	**
32, 42	Control	60	0.494 ± 0.075	
	BCLP	19	0.585 ± 0.107	***
	UCLP	43	0.536 ± 0.072	**
33, 43	Control	65	0.485 ± 0.058	
	BCLP	15	0.560 ± 0.117	***
	UCLP	25	0.511 ± 0.06	NS
34, 44	Control	62	0.467 ± 0.066	
	BCLP	11	0.547 ± 0.077	**
	UCLP	28	0.486 ± 0.780	NS
35, 45	Control	59	0.438 ± 0.055	
	BCLP	11	0.436 ± 0.063	NS
	UCLP	28	0.419 ± 0.058	NS
36, 46	Control	65	0.471 ± 0.064	
	BCLP	27	0.484 ± 0.077	NS
	UCLP	38	0.478 ± 0.058	NS
37, 47	Control	48	0.498 ± 0.074	
	BCLP	10	0.532 ± 0.078	NS
	UCLP	24	0.504 ± 0.066	NS

[a] C/R indicates crown-root; BCLP, bilateral cleft lip and palate; UCLP, unilateral cleft lip and palate, and NS, not significant.
* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

Intraexaminer reproducibility was examined by means of paired Student's *t*-tests. A statistical significance level of $P = .05$ was selected.

RESULTS

Crown heights and root lengths were measured and C/R ratios calculated for a total of 1397 teeth (600 for CLP, 797 for controls). Many teeth were not traced, especially from the CLP sample, mainly because they were missing, distorted, dilacerated, impacted, or incompletely developed. No teeth had marked attrition evident on panoramic radiographs.

Table 3. Differences in Mean C/R Ratios According to Cleft Type[a]

Tooth	Cleft Type	Mean C/R Ratio (N)	Standard Deviation	*P* Value
11, 21	BCLP	0.614 (13)	0.150	NS
	UCLP	0.564 (32)	0.061	
12, 22	BCLP	0.577 (12)	0.121	NS
	UCLP	0.544 (12)	0.077	
13, 23	BCLP	0.563 (10)	0.123	NS
	UCLP	0.511 (25)	0.084	
14, 24	BCLP	0.589 (8)	0.093	NS
	UCLP	0.539 (21)	0.075	
15, 25	BCLP	0.493 (9)	0.046	NS
	UCLP	0.492 (19)	0.065	
16, 26	BCLP	0.602 (25)	0.080	NS
	UCLP	0.613 (33)	0.106	
17, 27	BCLP	0.623 (12)	0.068	*
	UCLP	0.564 (23)	0.084	
31, 41	BCLP	0.651 (22)	0.125	**
	UCLP	0.564 (45)	0.080	
32, 42	BCLP	0.585 (19)	0.107	*
	UCLP	0.536 (43)	0.072	
33, 43	BCLP	0.560 (15)	0.117	NS
	UCLP	0.511 (25)	0.060	
34, 44	BCLP	0.547 (11)	0.077	*
	UCLP	0.486 (28)	0.080	
35, 45	BCLP	0.436 (11)	0.063	NS
	UCLP	0.419 (28)	0.058	
36, 46	BCLP	0.484 (27)	0.077	NS
	UCLP	0.477 (38)	0.058	
37, 47	BCLP	0.532 (10)	0.078	NS
	UCLP	0.504 (24)	0.066	

[a] C/R indicates crown-root; BCLP, bilateral cleft lip and palate; UCLP, unilateral cleft lip and palate; and NS, not significant.
* $P \leq .05$; ** $P \leq .01$.

Reproducibility testing of the two sets of data were correlated ($r > 0.97$), and no statistically significant difference was found ($P > .05$). The method of the error was 0.02 mm.

C/R ratios were higher for both BCLP and UCLP subjects than for controls, and this difference was statistically significant for all incisors. It was noted that C/R ratios of canines, premolars, and molars in both jaws were not affected in the UCLP group (Table 2). When data from the two CLP groups were pooled together, the C/R ratios of maxillary and mandibular incisors and of canines were significantly higher than those of controls. This was also true for the maxillary second molar and the mandibular first premolar.

Within the CLP group, BCLP subjects showed higher C/R ratios in general than did UCLP subjects, and for some teeth, this was significant ($P < .05$) (Table 3). When cleft-side and non–cleft-side maxillary teeth C/R ratios in UCLP subjects were compared, no statistically significant difference was found ($P > .05$).

C/R ratios did not show a consistent relation with gender in control subjects, for instance, they were

Table 4. Differences in Mean C/R Ratios According to Gender in Cleft and Control Samples[a]

Tooth	Gender	Cleft Mean C/R Ratio (N)	*P* Value	Controls Mean C/R Ratio (N)	*P* Value
11, 21	M	0.594 (28)	NS	0.508 (29)	NS
	F	0.554 (17)		0.529 (30)	
12, 22	M	0.558 (15)	NS	0.481 (27)	NS
	F	0.566 (9)		0.496 (26)	
13, 23	M	0.517 (20)	NS	0.476 (32)	NS
	F	0.538 (15)		0.499 (25)	
14, 24	M	0.546 (22)	NS	0.495 (22)	*
	F	0.574 (7)		0.559 (18)	
15, 25	M	0.508 (17)	NS	0.504 (27)	NS
	F	0.468 (11)		0.531 (27)	
16, 26	M	0.620 (33)	NS	0.587 (33)	*
	F	0.593 (25)		0.637 (29)	
17, 27	M	0.598 (19)	NS	0.526 (26)	*
	F	0.568 (16)		0.571 (26)	
31, 41	M	0.596 (34)	NS	0.494 (26)	NS
	F	0.589 (33)		0.521 (35)	
32, 42	M	0.543 (35)	NS	0.479 (29)	NS
	F	0.562 (27)		0.508 (31)	
33, 43	M	0.538 (21)	NS	0.475 (32)	NS
	F	0.520 (19)		0.494 (33)	
34, 44	M	0.497 (19)	NS	0.457 (31)	NS
	F	0.509 (20)		0.478 (31)	
35, 45	M	0.426 (19)	NS	0.429 (28)	NS
	F	0.422 (20)		0.447 (31)	
36, 46	M	0.490 (37)	NS	0.449 (30)	*
	F	0.467 (28)		0.489 (35)	
37, 47	M	0.525 (19)	NS	0.491 (20)	NS
	F	0.495 (15)		0.503 (28)	

[a] C/R indicates crown-root; NS, not significant.
* $P \leq .05$.

higher in females for some teeth, but for the rest males had higher values. No differences between female and male C/R ratios reached statistical significance (Table 4).

When crown heights and root lengths were compared separately in CLP subjects and their controls, it was noted that some roots were significantly shorter in CLP patients than in controls (Table 5). With regard to crown height, results showed that the crowns of some teeth were significantly shorter, but those of other teeth were significantly longer, in CLP subjects than in control subjects (Table 6).

DISCUSSION

Several studies have demonstrated that accurate reproducibility of panoramic radiographs and their diagnostic quality are heavily dependent on careful attention to positioning and processing.[25–27] The problem of vertical distortion, which is usually encountered when absolute heights and lengths are reported from panoramic radiographs, would be overcome by ratio calculations, as proportions of crown and root parts of the tooth would remain unchanged.[28] When C/R ratio measurements from panoramic radiographs were tested in one study, the authors concluded that tooth lengths and C/R ratios could be measured accurately from panoramic radiographs.[29]

A problem in studying unusual clinical conditions is use of a small study sample, which makes it difficult for investigators to reach relevant conclusions. This is why we had to add many data within the cleft group to have good numbers for comparisons. Within this limitation, C/R ratios were higher in the CLP group than in the control group, and were even higher in the BCLP group than in the UCLP group. This unfavorable ratio could be the result of shorter roots or longer crowns in CLP patients. No studies that have investigated C/R ratios and root lengths in these patients are available for comparison. Delayed root development, which is one type of disturbance in root development,[21] would result in short roots; this in turn may produce increased and unfavorable C/R ratios. This possibility is valid for causing short roots in CLP subjects, as several studies had found root development to be delayed in these patients when compared with normal reference populations.[30,31] In a recent study investigating differences in dental development between UCLP and BCLP patients, a significantly greater delay was noted for BCLP subjects than for UCLP subjects.[31]

Table 5. Differences in Mean Root Lengths Between Cleft and Control Subjects[a]

Tooth		N	Mean Height, mm	Standard Deviation	*P* Value
11, 21	Cleft	45	17.13	2.27	***
	No cleft	59	18.77	1.89	
12, 22	Cleft	24	15.35	2.79	***
	No cleft	53	18.22	2.07	
13, 23	Cleft	35	19.6	2.31	**
	No cleft	57	21.49	2.84	
14, 24	Cleft	29	16.34	1.84	***
	No cleft	40	18.06	1.91	
15, 25	Cleft	28	17.25	1.83	NS
	No cleft	54	17.53	2.09	
16, 26	Cleft	58	14.55	1.75	NS
	No cleft	71	15.02	2.1	
17, 27	Cleft	35	14.65	1.67	*
	No cleft	52	15.65	1.86	
31, 41	Cleft	77	13.98	1.89	**
	No cleft	64	15	2.27	
32, 42	Cleft	68	15.19	1.91	*
	No cleft	60	16.11	2.24	
33, 43	Cleft	41	18.83	2.21	NS
	No cleft	65	19.07	2.29	
34, 44	Cleft	42	17.65	1.57	NS
	No cleft	63	18.13	1.95	
35, 45	Cleft	40	19.08	2.2	NS
	No cleft	59	18.81	2.05	
36, 46	Cleft	64	17.73	1.97	*
	No cleft	65	18.56	1.81	
37, 47	Cleft	34	16.85	1.91	NS
	No cleft	48	17.39	1.95	

[a] NS, not significant.
* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

Table 6. Differences in Mean Crown Heights of All Teeth Between Cleft and Control Subjects[a]

Tooth		N	Mean Length, mm	Standard Deviation	*P* Value
11, 21	Cleft	45	9.78	1.26	NS
	No cleft	59	9.65	0.85	
12, 22	Cleft	24	8.42	1.01	NS
	No cleft	53	8.81	0.99	
13, 23	Cleft	35	10.20	1.48	NS
	No cleft	57	10.30	1.01	
14, 24	Cleft	29	8.92	0.83	*
	No cleft	40	9.37	0.89	
15, 25	Cleft	28	8.49	0.80	*
	No cleft	54	8.93	0.94	
16, 26	Cleft	58	8.72	0.76	*
	No cleft	71	9.06	0.85	
17, 27	Cleft	35	8.47	0.87	NS
	No cleft	52	8.47	0.68	
31, 41	Cleft	77	8.22	1.10	***
	No cleft	64	7.54	1.10	
32, 42	Cleft	68	8.28	1.03	*
	No cleft	60	7.87	1.02	
33, 43	Cleft	41	9.34	1.19	NS
	No cleft	65	9.18	1.11	
34, 44	Cleft	42	8.44	0.93	NS
	No cleft	63	8.41	0.93	
35, 45	Cleft	40	7.86	0.72	*
	No cleft	59	8.16	0.76	
36, 46	Cleft	64	8.40	0.75	NS
	No cleft	65	8.65	0.74	
37, 47	Cleft	34	8.55	0.92	NS
	No cleft	48	8.56	0.86	

[a] NS, not significant.
* $P \leq .05$; *** $P \leq .001$.

Teeth that showed less favorable C/R ratios in BCLP than in UCLP would be expected to be the least likely affected by the cleft (maxillary second molar, mandibular incisors, and first premolar). Findings that BCLP subjects had comparable C/R ratios to those in UCLP for the maxillary anterior teeth, and that UCLP cleft-side and non–cleft-side teeth C/R ratios were also comparable, lead to the suggestion of a shared genetic basis. This shared genetic basis may have a greater impact on C/R ratios than the direct effect of the cleft itself has on primordial tissues because effects are more pronounced when the patient has a bilateral rather than a unilateral cleft.

Males and females exhibited no differences in C/R ratios within the CLP group, but females had greater C/R ratios than males in the control group. This finding could be the result of longer roots in males or shorter roots in females. Many studies that investigated the effects of X and Y chromosomes on root growth in sex chromosome abnormalities have concluded that the promoting effect of the Y chromosome on growth of root length is greater than that of the X chromosome[19,32,33]; this could have been the cause of longer roots in males, thus reducing their C/R ratios. In a study investigating root-crown ratios in a healthy Finnish population, it was found that males had more favorable ratios—a fact that was concluded to be the result of their longer roots.[21] The fact that the CLP group was not affected could be the result of delay or could be the root-shortening effect of the etiologic factor of the cleft dominating over the sex gene effect.

It is interesting to note that maxillary incisors and canines had significantly shorter roots than those in the control group, but at the same time, this was not consistently so. In one study, root development rather than root length was compared for maxillary lateral incisors using cleft and noncleft sides.[9] It was found that root development was delayed for the cleft side, which was in agreement with the findings of previous studies.[11,34] Similarly, Demirjian's study[35] concluded that mechanisms controlling dental development are independent of somatic and sexual maturity and are highly influenced by the same etiologic factor as the cleft. Because some types of environmental insults during tooth development and genetic factors may result in short-rooted teeth,[14–20] CLP patients should be

considered as potentially having short roots, resulting in unfavorable C/R ratios.

With regard to crown height comparisons, the results were somehow inconsistent in that tooth crowns were shorter in some cleft patients, and in others they were longer (Table 6). In CLP subjects, enamel defects and abnormalities in shape and size of both deciduous and permanent teeth are far more common than in normal subjects[1,8,36]; this explains the deviation in crown height from normal in the current CLP sample. A recent study showed that occlusogingival measurements of tooth crowns in the casts of CLP patients were smaller than those of controls—not only in the affected maxillary dental arch, but also in the mandibular dental arch.[37] It is important, however, to be aware that study methods varied in that investigators used casts rather than radiographic assessments.

Early diagnosis of short roots in CLP patients may influence their orthodontic treatment strategy. In addition, these patients may require fixed prostheses to close edentulous spaces because missing teeth are commonly prevalent.

CONCLUSIONS

- CLP patients should be considered to have short roots and unfavorable C/R ratios.
- BCLP patients had significantly higher C/R ratios than did UCLP patients for some teeth.
- UCLP cleft-side and non–cleft-side C/R ratios were affected similarly, with higher C/R ratios.
- No differences were noted between male and female C/R ratios within the CLP group.

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