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A determination of the sensitivity of the dental pulp of primary maxillary anterior teeth to electrical stimuli in children with unilateral and bilateral clefts

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Abstract

A study was conducted to determine differences in pulpal sensitivity of the maxillary primary anterior teeth in groups of children with unilateral clefts of the lip, alveolar process and palate, bilateral clefts of the lip process, and children without clefts.

Thirty-nine children between the ages of 4 and 5 years with a total of 216 maxillary primary anterior teeth were tested using a pulp tester. The results indicated that maxillary primary anterior teeth distal to the cleft site are unaffected and demonstrate pulpal responses similar to the control group, while maxillary primary anterior teeth mesial to the cleft site are affected and demonstrate significantly less response to pulp testing compared to the control group.

The results of this study are important for the clinician in establishing a proper diagnosis and treatment plan for children with clefts.

The determination of the vitality of the dental pulp is a diagnostic adjunct in establishing the appropriate treatment for teeth in the primary dentition. A diagnosis is made based upon the integration of information derived from a history, clinical and radiographic examinations, and special diagnostic aids such as electric pulp testing.

Neural impulse transmission has yet to be explained fully. Scott (1965), Yamada (1969), and Matthews (1970) attributed neural impulse transmission to the presence of dental receptors. The role of acetylcholinesterase in neural conduction has been investigated by Rapp et al. (1964). Other factors cited as being related to neural impulse transmission have been the hydrodynamic movement of tubular contents (Kramer 1955; Brannstrom 1963; Mumford and Newton 1964; Brannstrom and Astrom 1972) and the role of polypeptides as neural modulators in the pulp (Kroeger 1968).

Electric pulp testers have been of value in suggesting the degree of sensitivity as an aid in determining the vitality of the dental pulp. Several variables, however, have been associated with electric pulp testing. These variables have been: (1) the use of unreliable or inaccurate instruments (Matthews and Searle 1974; Cooley and Robinson 1980); (2) unusual responses of individual teeth (Mumford 1959); (3) type of electrode media used (Martin 1969); and (4) individual differences in the clinical testing technique (Cooley and Robinson 1980).

Reynolds (1966) used a standard electric pulp tester and electric thermal tooth stimulator to determine whether thermal testing could be of more specific diagnostic value. The teeth tested were examined radiographically, clinically, and later histologically. Thermal stimulus with the thermoelectric stimulator did not distinguish among normal, inflamed, or necrotic pulp as determined by the histologic findings. The electric vitalometer however demonstrated an accuracy of 100% in diagnosing vitality and nonvitality, but could not distinguish the specific state of vitality.

The normal nerve distribution to the maxillary anterior teeth is derived directly from the filaments arising from the anterior superior alveolar nerve or from the superior dental plexus. The nasopalatine nerve may supplement innervation in the maxillary anterior region (Fischer 1933; Phillips and Maxmen 1941; Cook 1949; Olsen et al. 1955; Woodburne 1978; Basmajian 1980).

Congenital orofacial clefts have been shown to alter the distribution of the nerves to the teeth adjacent to the cleft site (King 1954; Bohn 1963; McKinstry 1984). McKinstry found an elevated threshold of response to electrical stimuli of the permanent maxillary anterior teeth in patients with complete unilateral and bilateral

clefts of the lip, alveolar process, and palate. The significance of this altered distribution in relationship to pulpal responsiveness of the primary teeth in children with clefts has yet to be determined.

Performance of dental procedures such as the administration of local anesthesia, intracoronal restorations, crown preparations, and pulpal therapy requires a knowledge of the pulpal status of the teeth adjacent to unilateral and bilateral clefts.

The purpose of this study was to determine whether differences existed in pulpal sensitivity to electrical stimuli: (1) between the primary maxillary anterior teeth among children with unilateral and bilateral complete clefts of the lip, alveolar process, and palate compared to those of noncleft children; (2) between central and lateral incisors of children with unilateral and bilateral complete clefts; and (3) between teeth on the cleft side in unilateral complete clefts compared to those on the noncleft side and between teeth on the right side in bilateral complete clefts compared to those on the left side.

Methods and Materials

The final sample consisted of 39 children from the Cleft Palate Center and the Department of Pediatric Dentistry at the University of Pittsburgh. The criteria for inclusion were: (1) the presence of sound and healthy primary maxillary anterior teeth (e.g., teeth free of caries, restorations, absence of mobility, abrasion, attrition or discoloration, and with no history of trauma); (2) absence of mental retardation; and (3) age ranging from 4 to 5 years so as to maintain appreciably similar root conditions related to the degree of root resorption (Knott and O'Meara 1967; Johnsen et al. 1979).

The subjects were divided into 3 groups. Two experimental groups were established — one consisting of 15 children with unilateral clefts of the lip, alveolar process, and palate, and the other consisting of 10 children with bilateral clefts of the lip, alveolar process, and palate. The control group consisted of 14 noncleft children matched by age to the 2 experimental groups.

Electric pulp tests were performed on 216 primary anterior teeth using a pulp tester (Model 2001 — Analytic Technology; Missoula, MT). To calibrate the instrument, the voltage and current output of the instrument were determined by the use of a voltmeter and Heathkit® resistor. The determination was made by connecting the lead from the probe tester to the voltmeter. A second lead was connected from the resistor to the tip of the pulp tester. The voltage reading was read on the voltmeter and the resistance was calculated. The resistance was adjusted to 100,000 ohms. This resistance was reported by Jones (1969) to correspond closely to the resistance of human enamel. The measurement of voltage and current at 100,000 ohms resistance was measured against the 50,000 ohms level to determine the consistency of the current output of the pulp tester.

The sweep rate of the pulp tester was adjusted to the #6 setting to produce a moderate increase in intensity of electrical current with the minimum current output of about 150μA. The teeth to be tested were isolated using cotton rolls and dried thoroughly using a compressed air syringe. The electrode tip of the pulp tester was dipped into a small amount of petroleum jelly to serve as an interface media between the tooth and the pulp tester. The amount of interface media utilized was a thin coating within the confines of the electrode tip. The electrode tip was applied flat onto the middle one-third of the crowns of the teeth tested in order to standardize the contact area and to maintain a uniform stimulus area throughout the study. The teeth were tested in a random order using the Latin Square method. Three responses were registered for each tooth tested. Lower readings of the pulp test responses were interpreted as a higher sensitivity to electrical stimuli and higher readings as lower sensitivity to electrical stimuli. A no-response reading was assigned when the digital display of the pulp tester demonstrated a value of ≥80.

Prior to the actual experiment, a pilot study was conducted using the previously calibrated pulp tester to determine whether any differences in responses existed between the 4- and 5-year-old children. Eight noncleft children, four aged 4 years and four aged 5 years, were utilized. The results indicated that there was sufficient variance among the 3 readings for each tooth on the 8 subjects, to suggest that the best method of data collection was to employ the mean value of the 3 readings. Also, no statistically significant differences were found in the pulp test responses between the 4- and 5-year-old children; therefore, the 2 age groups were pooled for the actual study.

The children were told that they were going to play a game to see what score they were going to receive as soon as their tooth tingled or began to feel warm.

The tell-show-do method was used to introduce the pulp tester by showing the digital display as the light of the probe tip turned on upon touching the operator's finger. The children were instructed to raise a hand at the first sensation of warmth or tingling in the tooth. The response level, as indicated on the digital display, was recorded for each tooth tested for the 3 study groups.

To ensure that the child experienced a sensation from the electric pulp tester, a false positive test as described by Johnsen et al. (1979) was utilized. If the child responded during the false positive test, the entire procedure was started over. Children responding to a second

false positive test were excluded from the study. This test was performed on each child for each tooth tested.

As a result of congenitally missing teeth in the children with clefts, each tooth was considered as a dependent variable due to the variable number of teeth in each individual patient. To test whether there was a difference in pulpal sensitivity to electrical stimuli of the maxillary anterior teeth of children with unilateral or bilateral clefts and without clefts, an extension of the median test was performed. The null hypothesis that the 3 groups are from populations with the same median will be rejected if the calculated value is greater than the tabled critical value at the appropriate df(2) and the predetermined level of significance (.05). All of the statistical analyses utilized in the current study were based on that of Marascuilo and McSweeney (1977).

The median test was utilized to determine whether there was a difference between central and lateral incisor pulpal sensitivity to electrical stimuli between children with unilateral clefts and those with bilateral clefts.

To determine whether any pulpal sensitivity differences existed between contralateral pairs of maxillary anterior teeth among children with unilateral clefts, bilateral clefts, and those without clefts, the sign test was performed.

Results

Differences in Pulpal Sensitivity Among Unilateral, Bilateral, and Control Groups

For the 39 maxillary right primary canines and 39 left canines tested, the median was 54.33 and 56, respectively. There was no statistically significant difference in the sensitivity to electrical stimuli among the bilateral, unilateral, and control groups.

Thirty-three maxillary right primary lateral incisors and 34 left lateral incisors were tested. The median value for the right laterals was 46.0 and for those on the left 49.0. A statistically significant difference in the sensitivity to electrical stimuli was found for both right and left primary maxillary lateral incisors among the unilateral, bilateral, and control groups. For the right the Chi-square value was 6.72, df = 2, significant at the 0.03 level, and for the left the Chi-square value = 8.897, df = 2, significant at the 0.02 level. The median value for the 38 maxillary right primary central incisors was 44.66 and for the 36 left was 49.0. There was a statistically significant difference in the sensitivity among the unilateral, bilateral, and control groups for both right and left central incisors. For the right the Chi-square value was 11.23, df = 2, significant at the 0.005 level, and for the left the Chi-square value = 6.972, df = 2, significant at the 0.03 level.

Differences in Pulpal Sensitivity Between Unilateral and Bilateral, Unilateral and Control, and Bilateral and Control

With the exception of the canines, the control group had consistently lower readings compared to the experimental (unilateral and bilateral) groups. Additionally, in all cases, both the unilateral and bilateral groups had significantly higher readings and therefore were less sensitive than the control group (Table 1). However, there was no statistically significant difference in sensitivity to electrical stimuli for any of the primary maxillary incisors of children with unilateral and bilateral clefts of the lip, alveolar process, and palate. Therefore, Table 1 demonstrates that the presence of a cleft is significant in pulp test response, but that the type of cleft is not significant.

There were no statistically significant differences in sensitivity to electrical stimuli between central and lateral incisors for both unilateral and bilateral cleft groups.

TABLE 1. Chi Square Test of Homogeneity of Proportions Among Groups

Tooth No.	P_k	$P_{k'}$	P_k-$P_{k'}$	$\sqrt{SE^2 \times X^2}$
	Unilateral	Bilaterial		
D	.643	.800	.157	.429
E	.750	.666	.084	.392
F	.692	.635	.067	.415
G	.714	.833	.119	.366
	Unilateral	Control		
D	.643	.230	.410	.337
E	.750	.143	.607	.392
F	.692	.214	.478	.327
G	.714	.230	.484	.315
	Bilateral	Control		
D	.800	.230	.570	.420
E	.666	.143	.523	.361
F	.625	.214	.411	.396
G	.833	.230	.603	.376

P_k and $P_{k'}$ are the proportions of readings greater than the median for pulp test response of each tooth tested. SE^2 = square of the standard error of proportion. $X^2 = 3.84$ at $p < .05$. D = Primary maxillary right lateral incisor. E = Primary maxillary right central incisor. F = Primary maxillary left central incisor. G = Primary maxillary left lateral incisor.

Differences in Sensitivity Between Contralateral Pairs of Maxillary Anterior Teeth

Due to missing lateral incisors in the bilateral group, the sample size was too small to measure the differences in pulpal sensitivity. For the unilateral group consisting of 13 children, 2 were excluded due to missing lateral incisors on the side of the cleft. The maxillary lateral incisors on the cleft side were less sensitive to electrical stimuli than the lateral incisors on the noncleft side. This difference was statistically significant at the 0.006 level. For the control group there was no sensitivity difference between the left and the right lateral incisors (Table 2).

There was a statistically significant difference in sensitivity between the central incisors in the unilateral cleft children at the .01 level with those on the cleft side having higher readings than those on the noncleft side. For the bilateral and control groups there was no difference in sensitivity between the right and left maxillary primary central incisors (Table 3). The same was true for the control group.

TABLE 2. Sign Test for Comparison between Cleft and Noncleft for Maxillary Incisors

Pair	*Central Incisor on Cleft Side (Xc)*	*Central-Incisor on Non-Cleft Side (Xn)*	*Direction of Difference*	*Sign*
1.	49.00	43.00	Xc > Xn	+
2.	NR	76.65	Xc > Xn	+
3.	NR	NR	Xc = Xn	o
4.	68.60	64.66	Xc > Xn	+
5.	50.33	40.00	Xc > Xn	+
6.	53.66	44.60	Xc > Xn	+
7.	66.00	28.33	Xc > Xn	+
8.	57.00	43.33	Xc > Xn	+
9.	NR	NR	Xc = Xn	o
10.	49.33	48.00	Xc > Xn	+
11.	NR	38.00	Xc > Xn	+
12.	43.33	45.33	Xc < Xn	−

N = 10. x = 1. p = .011. X = Number of fewer signs. N = Number of pairs that show a difference.

Discussion

The sensitivity of the dental pulps of primary maxillary teeth is associated with the anatomic distribution of nerves in the area. The cleft produces a disturbance from this normal distribution of nerves. In the normal (noncleft) palate, the maxillary anterior teeth derive their neural supplies from the anterior superior alveolar nerve on either side of the maxilla (Olsen et al. 1955; Woodburne 1978; Basmajian 1980) with contributions from the nasopalatine nerve (Fischer 1933; Phillips and Maxmen 1941; Cook 1949). These conditions could be in the form of neural fibers being sent directly to the teeth (Phillips and Maxmen 1941) by exchanging fibers to form the superior dental plexus to enter the apices of the maxillary anterior teeth or by uniting with the anterior superior alveolar nerve (Fischer 1933).

The presence of a cleft alters the normal course of blood vessels and nerves in the maxillary complex. Cook (1949) stated that it was impossible for the anterior superior alveolar nerve to supply the maxillary incisors in individuals with bilateral cleft lip and palate. King (1954) reported that in abnormal conditions, nerves may wander far from their normal courses. This finding was confirmed by the dissections and histologic serial sections of cleft specimens in the investigation of Bohn (1963). Bohn's findings have shown that in bilateral clefts, the maxillary central and lateral incisors derive their neural supply from the nasopalatine nerve alone. Cook (1949) and Olsen et al. (1955) confirmed this finding in previous studies.

In unilateral complete clefts of the lip, alveolar process, and palate, the premaxilla on the cleft side derives its main neural supply from the nasopalatine nerve of the same side. However, there are contributions across the midline from the anterior superior alveolar nerve from the noncleft side (Bohn 1963). The anterior superior alveolar nerve was found distal to the cleft and sent direct supplies to the primary canine tooth (Bohn 1963).

Therefore, the presence of a cleft disturbs the neural supply to the tissues surrounding the clefts. As a result, the sensitivity of the teeth anterior to the cleft is decreased which could support the contention that the presence of a cleft causes an increased threshold of response to electrical stimuli.

The sensitivity of the primary canines was not significantly different between the cleft (unilateral and bilateral) and the noncleft (control) groups. The sensitivity to electrical stimuli between the canine on the cleft side and the canine on the noncleft side was not significantly different in the unilateral group. There was also no significant difference in sensitivity to electrical stimuli between the contralateral maxillary canines in the bilateral cleft group. These teeth are distal to the cleft. Bohn's findings (1963) have shown that the anterior superior alveolar nerve directly innervates the primary canine teeth. The nerve supply of these teeth is not altered by the presence of a cleft. Therefore, the maxillary canine teeth have the same sensitivity to electrical stimuli as in the noncleft palates. The influence of a cleft by limiting the neural supply to the premaxillary area on the cleft side of the unilateral cleft palates is expressed by a decreased sensitivity of the maxillary incisors on the side of the cleft. The bilateral cleft of the palate influences the sensitivity of the maxillary central incisors. For the bilateral cleft group, there was an inadequate tooth sample to determine whether the

TABLE 3. Sign Test for Comparison Between Cleft and Noncleft for Lateral Incisors

Pair	*Lateral Incisor on Cleft Side (Xc)*	*Lateral Incisor on NonCleft Side (Xn)*	*Direction of Difference*	Sign
1.	50.00	44.33	Xc > Xn	+
2.	46.00	39.66	Xc > Xn	+
3.	67.00	64.00	Xc > Xn	+
4.	NR	NR	Xc = Xn	o
5.	48.00	49.33	Xc < Xn	−
6.	59.00	47.66	Xc > Xn	+
7.	54.00	35.65	Xc > Xn	+
8.	55.66	39.33	Xc > Xn	+
9.	NR	NR	Xc = Xn	o
10.	66.00	41.66	Xc > Xn	+
11.	52.00	40.66	Xc > Xn	+
12.	43.33	36.00	Xc > Xn	+
13.	48.00	40.33	Xc > Xn	+

N = 11. x = 1. $P = .006$ X = Number of fewer signs. N = Number of pairs that show a difference.

maxillary lateral incisors on one side of the cleft were more or less sensitive to electrical stimuli as compared to their contralateral teeth on the other side of the cleft.

Except for the canines, the results of the present study on primary teeth agree with those of McKinstry (1984) for permanent teeth. McKinstry found a decrease in sensitivity for the permanent maxillary canines, centrals, and right lateral incisors. He did not find a significant difference for the left lateral incisor which was attributed to his small sample size. In this study a decreased sensitivity was only found for the primary central and lateral incisors in children with unilateral and bilateral clefts. A lack of significant differences in sensitivity to electrical stimuli between unilateral and bilateral cleft groups also was found in both studies. Thus, apparently sound, healthy teeth of children with clefts, as evidenced by clinical examination, may not respond to the electric pulp testing.

Matthews and Searle (1974) stated that the maximum current output by which one could be sure of exciting all vital nerves in the pulp without running the risk of exciting the nerves in the periodontal tissues has not yet been determined.

The maximum current output that the Analytic Technology Model 2001 emits is 155μA. It would be inaccurate to presume that the teeth tested did not respond to the pulp tester but, instead, these teeth did not register a response at the maximum current output this pulp tester had been calibrated to emit.

It is important to recognize that decreased sensitivity of the dental pulps of primary teeth in children may not be necessarily indicative of nonvitality, but may be attributed to an altered source of innervation since the vitality of teeth is based on the blood supply to the dental pulp.

Rapp et al. (1964) stated that as the primary teeth undergo root resorption, degenerative changes appear in the nerves, and the quantity of neural tissue decreases. And Johnsen et al. (1979) found decreased sensation to electrical stimuli associated with increased vertical resorption of the roots of primary canines. Thus, the pulp test responses from primary teeth undergoing the normal process of resorption may not reflect the status of the pulp and have little diagnostic value in determining pulp vitality.

Previous studies (Knott and O'Meara 1967) reported that for both sexes, the median ages at initial resorption for the primary central incisor teeth in each arch was 5.5 years and for the lateral incisors was 6 years. The same investigators reported median ages of root resorption of primary canines as 8.5 and 8.8 years, respectively, for the mandibular and maxillary canines in boys and 7.4 and 7.9 years in girls. Based on these data, the teeth tested in the present study most likely had very little or no resorption.

In addition, appreciably similar root conditions were ensured by utilizing a narrow age range among the subjects in this study.

Summary and Conclusions

An investigation was conducted to determine any differences in sensitivity to electrical stimuli of the dental pulps of children without clefts and those with complete unilateral and bilateral clefts of the lip, alveolar process, and palate. Thirty-nine subjects 4-5 years of age were included in this study. The sample consisted of 2 experimental groups of 15 unilateral cleft subjects and 10 bilateral cleft subjects, and the control group of 14 noncleft subjects.

All of the 6 primary maxillary anterior teeth were tested in a random order using a pulp tester. A total of 216 teeth were tested 3 times. The findings of this study allow the following conclusions to be drawn.

1. The dental pulps of the primary maxillary central and lateral incisors in children with unilateral and bilateral clefts of the lip, alveolar process, and palate have a significantly lower sensitivity to electrical stimuli than the same teeth in children with normal (noncleft) palates at the .05 significance level.
2. There is a significant decrease in sensitivity to electrical stimuli between the maxillary primary central incisor on the cleft side compared to the maxillary primary central incisor on the noncleft side at the .05 significance level in children with unilateral clefts of the lip, alveolar process, and palate.

3. The maxillary primary lateral incisor on the cleft side has a significantly lower sensitivity than the maxillary primary lateral incisor on the noncleft side at the .05 significance level in children with unilateral clefts of the lip, alveolar process, and palate.
4. The sensitivity to electrical stimuli of the dental pulps of the primary maxillary canines of the cleft groups does not differ significantly from the noncleft group at the .05 significance level.
5. There is no significant difference in sensitivity to electrical stimuli of the dental pulps of the maxillary incisors of children with unilateral and bilateral clefts of the lip, alveolar process, and palate at the .05 significance level.
6. The dental pulps of the primary maxillary incisors of children with unilateral and bilateral clefts of the lip, alveolar process, and palate have significantly lower sensitivity to electrical stimuli compared to the noncleft children at the .05 significance level.
7. The sensitivity of the maxillary primary central incisors is not significantly different from the sensitivity of the maxillary primary lateral incisors in the unilateral cleft group at the .05 significance level.
8. There is no significant difference in sensitivity to electrical stimuli of the pulps of the maxillary primary central and lateral incisors of the bilateral group at the .05 significance level.
9. Additional research is required to establish a histologic basis for the findings in this study.
10. Additional research utilizing a larger sample would be beneficial in substantiating further the current investigation.

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