Variations in Craniofacial Morphology with Severity of Isolated Cleft Palate

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Cephalometric X-ray studies were carried out in 90 adult males with isolated cleft palate operated upon by the same method. The results were evaluated according to the extent of the clefts (complete, incomplete, or soft palate alone). But for a few exceptions the neurocranium and the cranial base showed no substantial deviations. Similarly, as in cleft lip and palate, a shortening of maxillary depth and a deficient mandibular growth were recorded, with no reduction of the vertical growth of the upper face, retroclination of the dentoalveolar maxillary component or increase of the interocular distance noted. No posterior displacement of the maxilla was found. The two observed deviations resulted in the retrusion of the upper and lower jaws, the flattening of the skeletal profile, impaired maxillomandibular relations and limitation of anterior growth rotation. Soft palate clefts were associated with less retrusion of the maxilla, while the growth deficiency of the mandible was even more marked. The least shortening of the mandible occurred in complete clefts. In general, incomplete clefts were associated with the most marked changes. The flattening of the skeletal profile in complete and incomplete clefts was masked by an increased thickness of the upper lip. Soft palate clefts were associated frequently with a shorter hard palate. Our results were in agreement with experimental knowledge of the role played by the mandible in the development of isolated cleft palate.

The present study is similar to our previous report on craniofacial changes in unilateral cleft lip and palate (Šmahel and Brejcha, 1983), and the same criteria were used for the selection of patients. The aim of this report is to describe in more detail the adult craniofacial morphology with isolated cleft palate in relation to the extent of the cleft. This report is based on cephalometric X-ray measurements, while somatometric, cephalometric and somatoscopic studies which were carried out in the same series are reported elsewhere (Šmahel, 1983).

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Materials and Methods

A series of 90 Czech males, ranging in age from 20 to 40 years, with repaired isolated cleft palate (CP) and without any associated major malformations were examined. The following subgroups were identified: complete clefts extending up to the incisive foramen (CP_c, n = 32), incomplete clefts extending at least to one third of the hard palate (CP_i, n = 32), and clefts of the soft palate alone (CP_s, n = 15). The study did not include patients with cleft soft palate with a notch into the hard palate and individuals with submucous clefts.

At the time of the follow-up examination the mean age in individual subgroups was as follows: CP_c = 29.66 years, CP_i = 27.84 years, CP_s = 30.13 years, and a group of controls 27.18 years. The surgical technique used for the primary repair of the palate was a pushback, usually including pharyngeal fixation. The mean age at the time of palatoplasty showed no significant differences between individual subgroups (CP_c = 4.54, CP_i = 5.11, CP_s = 5.17 years), or with the previously described unilaterals (CLP_{uni} = 4.91 years) with a range of 2 to 7 years. The 50 controls consisted of volunteers treated because of injuries and university students. Body height and weight in this series corresponded exactly to the norm for the Czech adult population. It was described in more detail in our previous paper (Šmahel and Brejcha, 1984).

The cephalometric points and reference lines used throughout our studies (Figures 1–3) were identical to those in our earlier report (Šmahel and Brejcha, 1983). Since the posterior nasal spine (Pns) did not develop in isolated cleft palate, two other points were developed: Pl (palatale)—the most posterior point of the palatal processes and Pmp (pterygomaxillare palatinum)—the intersect of the palate plane with the pterygomaxillary fissure.

The perpendicular distance between the point and the reference line was designated as Cd-NSL, angle as N-S-Ba, or as a fraction of reference lines ML/RL and the thickness of soft tissues of the profile, e.g. at the level of the soft tissue pogonion Pg_t' etc. (Ss_t' and Pr_t were measured in parallel with the palate line PL, Id_t and Sm_t' as the minimum thickness and Pg_t' perpendicular to the facial line N′-Pg′). In anteroposterior projection the perpendicular distances between all facial points and MSL and HL were measured and the values obtained used for the evaluation of asymetries. Deviations of medial facial structures (Bsptn, Intis, Id and Gn) were determined from MSL at the point C.

The numbers of cases were reduced in dimensions measured from the apex of the upper incisors (Is) by 3 cases in CP_c and by 4 cases in CP_i because of missing teeth.

Results

The results are presented in Tables 1–4 and Figures 4–7.

NEUROCRANIUM: The height of the neurocranium (Ba-Br) was reduced in all subgroups, while its length (N-Op) and width (Eu-Eu) remained unchanged. Contrary to CLP_{uni} the minimum frontal width (Lf-Lf) showed no increase in any subgroup, but the posterior rotation of the cranial vault was recorded usually as well (N-S-Br, N-S-L, N-S-I, Op-NSL). The reduction of the slope of the frontal bone attained the significance level in incomplete clefts only (S-N-F).

CRANIAL BASE: No substantial changes in the configuration of the cranial base were recorded. Reduction of its total length (N-Ba) resulted from the slight pre- and postsellar reduction (N-S, S-Ba) and angle N-S-Ba reduction.

BONY NASOPHARYNX: As compared to CLP_{uni} its length (Pmp-Ba) was only slightly reduced, while its height (S-Pmp) was unchanged.

UPPER FACE: In contrast to cleft lip and palate there were no changes in the interorbital (Mo-Mo) or biorbital (Lo-Lo) distances. The nasal cavity, however, was somewhat wider (Apt-Apt) in complete clefts, although the width of the dentoalveolar arch at its base (Em-Em) was slightly decreased. Vertical dimensions were not reduced within the upper face in any subgroup with isolated cleft palate.

In complete and incomplete clefts the reduction in depth and retrusion of the maxilla (Sp-Pmp, Ss-Pmp, S-N-Ss, S-N-Pr) was significant. The shortening of maxillary depth was accounted for by its posterior segment alone (K-Pmp), except in complete clefts where, as in CLP_{uni}, both segments were affected (Sp-K, K-Pmp). A cleft of the soft palate alone was not associated with a significant retrusion of the maxilla (S-N-Ss) though maxillary depth was somewhat reduced (Ss-Pmp).

THE LOWER JAW: There were certain differences in the configuration of the lower jaw between individual subgroups. In the incomplete cleft palate it was almost identical with that in CLP_{uni}. Virtually identical was the shortening of the body and ramus (Pgn-Go, Cd-Go), the obtuse gonial angle (ML/RL), the acute chin angle (CL/ML), the steeper slope of the body (ML/NSL) and the retroinclination of incisors (IIL/ML). There was also an identical retrognathia (S-N-Sm, S-N-Pg) as well as the

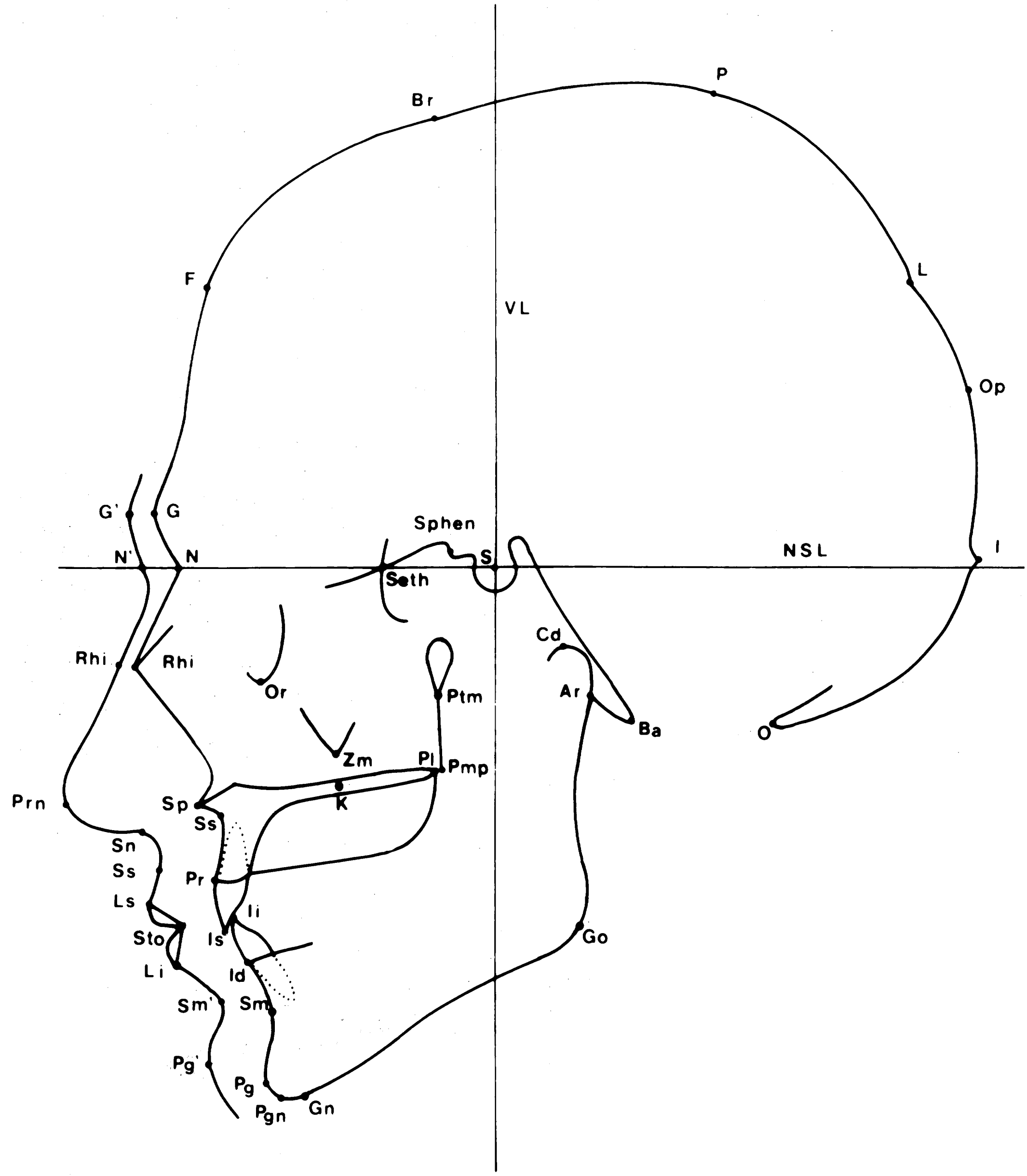

FIGURE 1. Cephalometric points used for the assessment of lateral X-ray films: **SP**—tip of the anterior nasal spine; **Ar** (articulare)—intersection of inferior contour of the clivus and posterior contour of the ramus; **Ba** (basion)—most posteroinferior point on the clivus; **Br** (bregma)—intersection of the coronal suture and lamina externa of the cranial vault; **Cd** (condylion)—most superior point on the condylar head; **F** (frontale)—intersection of the perpendicular to the dimension N-Br through its midpoint and lamina externa of the cranial vault; **G** (glabella)—most prominent point of the supraorbital ridges; **Ǵ** (soft glabella)—point on the soft profile contour over G parallel to NSL; **Gn** (gnathion)—lowest point of the mandibular symphysis; **Go** (gonion)—point on the angle of the mandible determined by the axis of ML/RL angle; **I** (inion)—top of the protuberantia occipitalis externa; **Id** (infradentale)—point of gingival contakt with lower central incisor; **Ii** (incision inferius)—incisal tip of the lower central incisor; **Is** (incision superius)—incisal tip of the upper central incisor; **K**—Zm projected on the palate line PL; **L** (lambda)—intersection of the lambdoid suture and lamina externa of the cranial vault; **Li** (labrale inferius)—margin of the vermilion of the lower lip, **Ls** (labrale superius)—margin of the vermilion of the upper lip; **N** (nasion)—most anterior point on the frontonasal suture; **Ň** (soft nasion)—intersection between NSL and soft profile contour; **O** (opisthion)—most posterior point of the foramen magnum located by the prolongation of the posterior wall of the spinal canal up to the occipital bone; **Or**

growth in vertical direction (N-S-Pgn). Only the anterior height of the mandible (Ii-Gn) was not increased (as in the other subgroups). On the contrary in a complete cleft palate the length of the mandibular body showed only very little reduction (Figure 7) and therefore no mandibular retrognathia was recorded. The adaptation leading to an overbite resulted under these conditions in an even more acute angle of the chin and in a more marked retroinclination of the lower incisors. However the overall mandibular growth was not shifted towards the vertical direction. The flattening of the gonial angle and the steeper slope of the body were less marked. The mandibular ramus was significantly shortened in all subgroups. Thus the mandibular angle was situated at a higher level (Ar-tGo) but it remained unchanged in anteroposterior direction (Go-VL).

Contrary to expectations the mandibular body was somewhat shorter in clefts of the soft palate alone as compared to incomplete cleft palate and the total mandibular length obtained by the addition of the length of the ramus with that of the body yielded the lowest recorded values (it was smaller than in CLP_{uni}). Therefore there was a retrognathia of the mandible with a more acute chin angle and retroinclination of incisors. However the latter changes were slighter than in the other subgroups because of the smaller maxillary retrusion. As in CLP_{uni}, none of the investigated subgroups showed deviations of the width of the lower jaw (Go-Go), of the inclination of its ramus (RL/NSL) or of the position of the mandibular joint (N-S-Cd, Cd-NSL).

FACIAL PROFILE: A flatter facial skeletal pattern (N-Ss-Pg) was found in complete and incomplete clefts. The soft tissue profile (N′-Sn-Pg′, N′-Prn-Pg′) was less obvious since the deviation was masked in complete and incomplete clefts by the compensating larger thickness of soft tissues of the upper lip (at the level of Ss′ and Pr regularly $p < 0.001$). Because of the marked adaptive dentoalveolar retroinclination on a mandible in complete clefts, this subgroup had an increased thickness of soft tissues also in the lower lip (Id_t, Sm_t'). This did not represent an actual hypertrophy but rather an extension of an intact lip into the vestibular space (Figure 8). In cleft soft palate there was never a compensatory increase of lip thickness which was probably due to the fact that the skeletal profile was not flattened. Compared to CLP_{uni} (Figures 4, 5), an isolated cleft palate was associated with a slighter retrusion of the soft profile of the upper face, including the nose, and resembled more closely the pattern in controls (S-N′-Ss′). The distance between the tip of the nose and the anterior spina (Prn-Sp) was not reduced except for CP_s. The soft profile of the lower jaw corresponded rather to the pattern in CLP_{uni} (S-N′-Sm′, S-N′-Pg′), except for complete clefts. The position of the soft chin in relation to the upper lip was similar to controls (Ss′-N′-Pg′) and differed from CLP_{uni} where, due to retrocheilia, the profile of the lower face was steep (Figures 5, 6). A slight deviation occurred only in complete clefts (similarly as Ss′-N′-Sm′). Neither the depth of the nose (Prn-Sn) and contrary to CLP_{uni}, nor the height of the upper lip (Sn-Ls, Sn-Sto) were reduced.

(orbitale)—lowest point of the orbit; **Op** (opisthocranion)—point on the surface of the cranial vault farthest from nasion; **P** (parietale)—intersection of the perpendicular to the dimension Br-L through its midpoint and lamina externa of the cranial vault; **Pg** (pogonion)—most anterior point on the bony chin; **Pǵ** (soft pogonion)—most anterior point on the soft tissue chin; **Pgn** (prognathion)—point on the mandibular symphysis farthest from Cd; **Pl**—tip of the posterior nasal spine resp. most posterior point of the palatal processes; **Pmp**—intersection of the palate line with the fissura pterygomaxillaris; **Pr** (prosthion)—point of gingival contact with upper central incisor; **Prn** (pronasale)—point on the top of apex nasi; **Ptm** (pterygomaxillare)—most inferior point of fossa pterygopalatina where fissura pterygomaxillaris begins; **Rhi** (rhinion)—most anteroinferior point on the nasal bone; **Rhí** (soft rhinion)—point on the soft profile contour over Rhi; **S** (sella)—centre of sella turcica; **Sm** (supramentale)—deepest point on the anterior contour of the mandibular symphysis; **Sḿ** (soft supramentale)—deepest point on the soft contour of the lower jaw; **Sn** (subnasale)—point at which columella merges with the upper lip; **Sphen**—Sphenoidale; **Ss** (subspinale)—deepest point of the subspinal concavity; **Sś** (soft subspinale)—deepest point of the upper lip; **Sto** (stomion)—point of contact of the upper and lower lip; **Zm** (zygomaxillare)—apex of the convexity of the lower margin of os zygomaticum i.e. lower margin of sutura zygomaticomaxillaris.

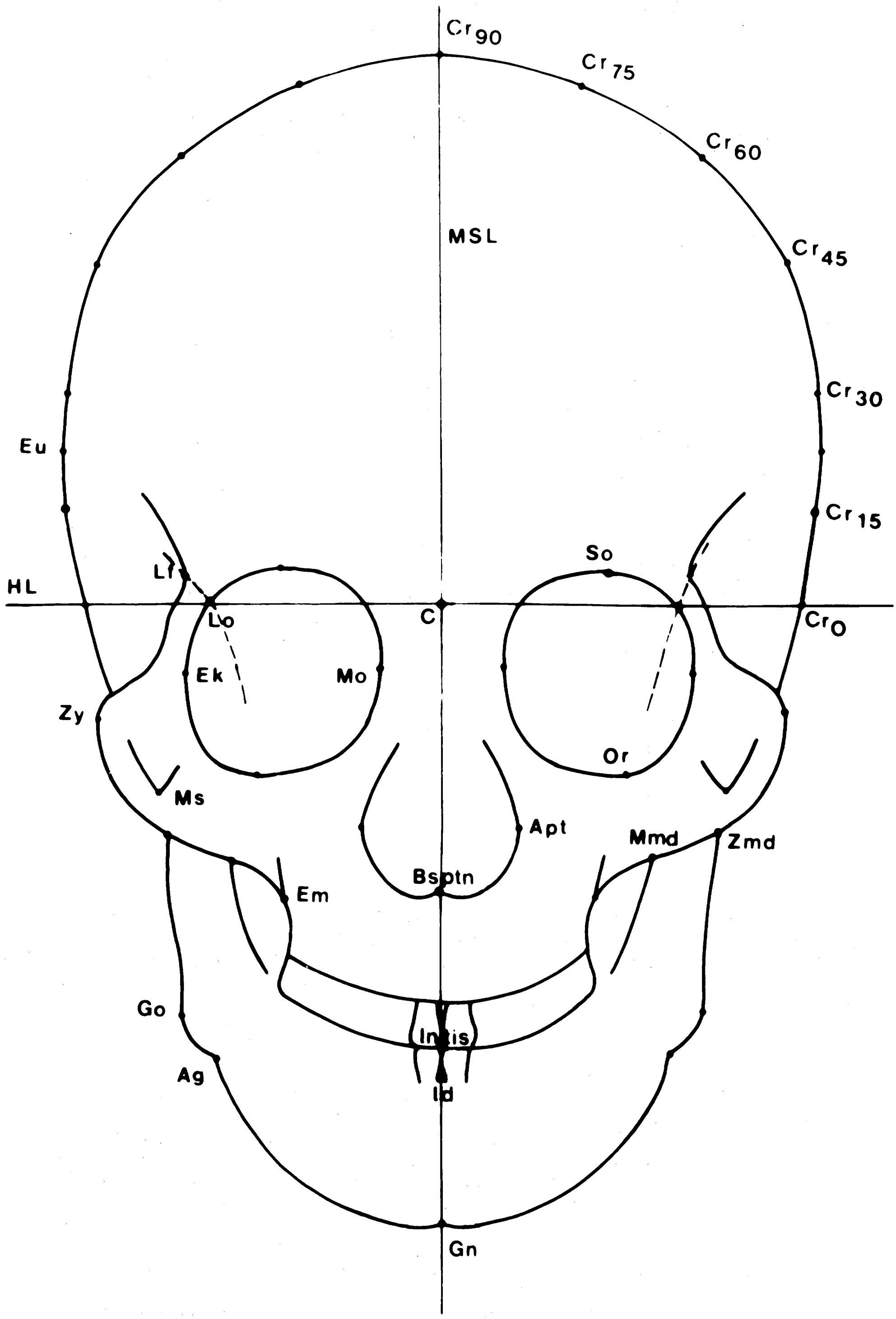

FIGURE 2. Cephalometric points on anteroposterior X-ray films and the method (see text) of construction of mediosagital line: **Ag** (antegonion)—highest point in the antegonial notch; **Apt** (apertion)—most lateral

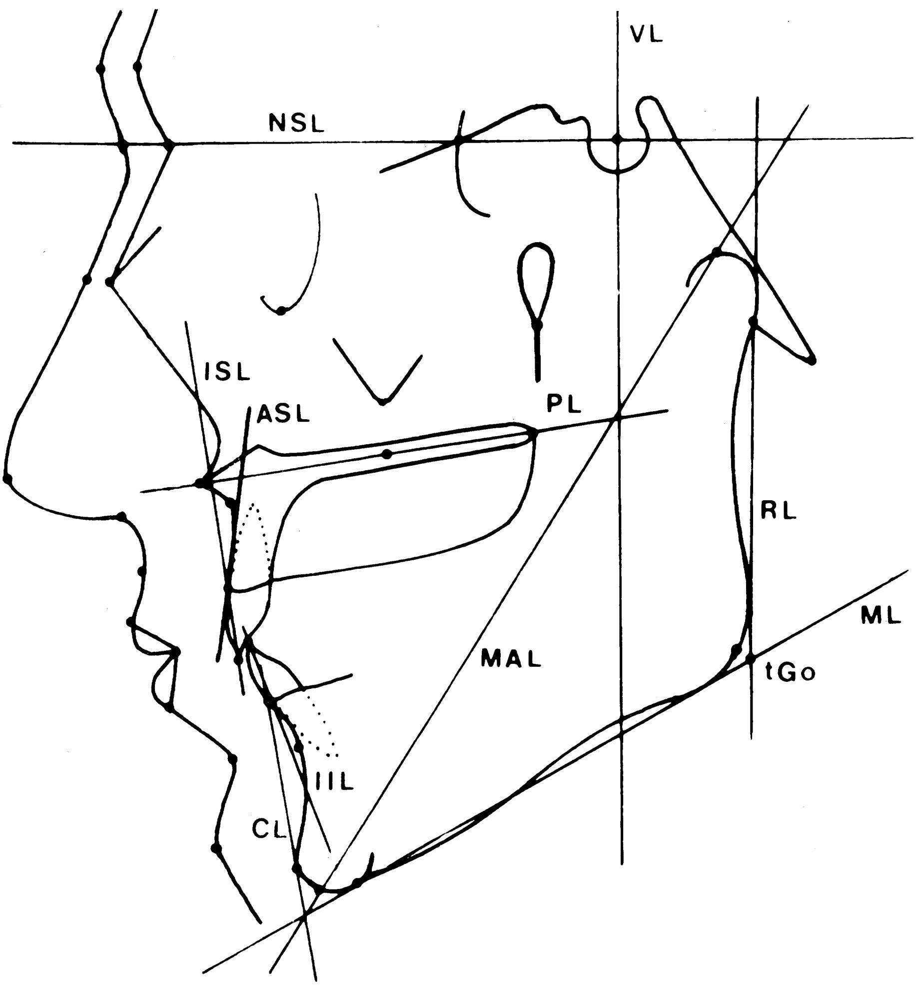

FIGURE 3. Reference lines plotted on lateral X-ray films (NSL = line through N and S, VL = perpendicular to NSL through S, PL = line through Sp and Pl, CL = line through Pg and Id, ML = tangent to the mandibular body through Gn, RL = tangent to the mandibular ramus through Ar, MAL = line through Pgn and Cd, ASL = tangent to the maxillar alveolar process through Pr, ISL = line through Is and Pr, IIL = line through Ii and Id, tGo = tangenta gonion point—intersection of ML and RL).

point of the nasal cavity; **C**—intersection of MSL and HL; **Cr_{60}** (craniale)—intersection between lamina externa of the cranial vault and line drawn from point C under the slope of 60° from HL, etc; **Ek** (ectoconchion)—most lateral point of the orbital contour; **Em** (ectomaxillare)—intersection of lateral contour of upper alveolar process and lower contour of maxillozygomatic process of the maxilla; **Eu** (euryon)—most lateral point of the cranial vault; **Gn** (gnathion)—notch of the center of the convexity of the mandibular lower margin; **Go** (gonion)—most lateral point of the mandibular angle; **Id** (infradentale)—bone margin between the lower medial incisors; **Intis** (interincision)—notch between incisal edges of the upper medial incisors; **Lf** (laterofrontale)—point of intersection between lateral margin of the ala major and lateral margin of the proc. zygomaticus of the frontal bone; **Lo** (lateroorbitale)—point of intersection between lateral margin of the ala major and contour of the orbita; **Mmd** (maxillomandibulare)—intersection between lower margin of the maxilla and medial contour of the mandibular ramus; **Mo** (medioorbitale)—most medial point of the orbital orifice; **Ms** (mastoideale)—top of the proc. mastoideus; **Or** (orbitale)— lowest point of the orbital orifice; **So** (supraorbitale)—highest point of the orbital orifice; **Zmd** (zygomandibulare)—intersection between lower margin of the zygomatic bone and lateral contour of the mandibular ramus; **Zy** (zygion)—most lateral point on the zygomatic bone.

TABLE 1. Cranial Dimensions in Adult Males with Isolated Complete (CP_c) and Incomplete (CP_i) Cleft Palate, Cleft of the Soft Palate Only (CP_s), and Unilateral Cleft Lip and Palate (CLP_{uni}) All Compared To Controls

Variable	CP_c	CP_i	CP_s	CLP_{uni}	*Control*
Neurocranium					
N-Op	−0.20	−0.23	−2.84	−1.35	191.64
Eu-Eu	−2.67	−0.23	−0.39	−0.98	163.39
Lf-Lf	−1.32	−0.32	−2.22	+2.39^{xx}	109.29
Ba-Br	−3.05^{x}	−5.08^{xxx}	−4.79^{xx}	−3.30^{xx}	152.52
Ba-O	−0.64	−0.05	+0.05	−1.14^{x}	37.52
Ms-Ms	−1.35	−1.94	−2.08	−1.39	120.41
S-N-F	−1.44	−2.25^{x}	−1.67	−2.55^{xxx}	85.00
N-S-Br	+1.20	+2.04^{x}	+1.09	+2.03^{x}	82.18
N-S-L	+2.48^{x}	+3.73^{xxx}	+3.52^{x}	+3.21^{xx}	144.08
N-S-I	+2.20	+2.35	+3.27	+2.82^{x}	179.46
Op-NSL	−4.47	−5.59^{x}	−7.72^{x}	−5.63^{x}	42.72
Cranial base					
N-Ba	−3.21^{xx}	−2.18	−3.44^{x}	−1.89^{x}	113.84
N-S	−0.76	−1.13	−1.51	−1.75^{xx}	75.04
S-Ba	−1.73^{x}	−0.94	−0.92	+0.09	49.32
N-S-Ba	−2.57^{x}	−0.94	−2.96	−1.38	132.16
N-Sphen-Ba	−0.85	−0.42	−0.46	−0.79	133.26

^{x} $p < 0.05$ ^{xx} $p < 0.01$ ^{xxx} $p < 0.001$
^{x} Significant differences between clefts and controls

THE FACE AS A WHOLE: The total facial height (N-Gn, N′-Pg′) was increased only in incomplete clefts due to the prolongation of the jaw portion of the face occurring in only this subgroup (Sp-Pg). This elongation was caused by the changed relations in the dental area and by the increased frequency of malocclusion, as illustrated by the increased distance Pr-Id. Since complete clefts were associated with a significant reduction of the posterior facial height (S-Go) while in incomplete clefts the anterior facial height (N-Gn) has increased theirrelationship showed in both subgroups identical changes, which were of the same degree as in CLP_{uni} (CP_c 64.30% CP_i 64.21%, CLP_{uni} 64.38%). Thus the anterior growth rotation (counterclockwise) was limited to the same extent. Soft palate cleft was associated only with slight changes of the anterior and posterior facial height and therefore the relation between both dimensions was similar to the controls (66.68% as compared to 67.69%).

MAXILLOMANDIBULAR RELATIONS: Both complete and incomplete clefts were accompanied by an impairment of sagittal (Ss-N-Sm) and vertical (ML/PL) maxillomandibular relations. In soft palate cleft the deviations from normal were small because of the similar retrusion of both jaws and the slightly steeper slope of the mandibular body. Since a retroinclination of the upper incisors and of the alveolar process did not occur, the impaired sagittal maxillomandibular relations in complete and incomplete clefts could be compensated by the adaptation of the dentoalveolar mandibular component resulting in an overbite (the frequency was 63.6% in complete clefts, 55.6% in incomplete clefts, 76.5% in cleft soft palate, and 88% in controls).

FACIAL ASYMMETRY: X-ray films in anteroposterior projection failed to disclose any significant differences between the dimensions of the right and left sides, or any deviations of medial facial structures. Only the deviation of the lower part of the nasal septum (dev. Bsptn) could show minor changes.

CERVICAL SPINE: In our series of 90 patients X-ray films disclosed fusion of cervical vertebrae in three individuals (3.33%).

Discussion and Comparison

Our findings showed numerous similarities, but some differences with the observations recorded earlier in cleft lip and palate (Šmahel and Brejcha, 1983). The

TABLE 2. Upper Face Dimensions in Different Cleft Types Compared to Controls (Explanatory Notes See Tab. 1)

Variable	CP_c	CP_i	CP_s	CLP_{uni}	Control
Width					
Zy-Zy	−0.74	−0.30	−2.65^{x}	+0.56	147.18
Mo-Mo	+0.60	+0.07	−0.63	+2.88^{xxx}	26.90
Lo-Lo	−0.21	+1.13	−0.86	+2.08^{xx}	101.59
Ek-Ek	−1.31	−0.81	−2.65^{x}	+0.99	109.65
Apt-Apt	+2.02^{x}	+1.33	0.00	+1.80^{xx}	34.67
Em-Em	−1.60	−2.41^{xx}	−2.08	+0.34	68.35
i. interorb.	+0.77	+0.17	−0.06	+2.27^{xxx}	24.61
Height					
N-Rhi^{ˇ}	−0.16	+1.75	+2.39^{xx}	+2.47^{xxx}	24.94
N-Sp	−0.23	+0.67	−0.01	−1.92^{x}	57.14
N-Pr	−0.69	+1.34	−0.17	−0.51	75.44
Is-PL	−0.59	+0.41	−0.27	+0.76	30.80
Pmp-NSL	−0.27	−0.58	−0.39	−1.06	48.86
Zm-NSL	−0.45	−0.36	+0.02	−0.98	48.58
Or-NSL	−0.47	+0.13	+0.47	+0.18	28.06
S-Pmp	+0.09	−0.63	−0.07	−1.77^{xx}	50.54
N′-Prn	+1.32	+2.16^{x}	+1.19	−0.20	59.34
N′-Sn	+0.46	+1.34	+0.49	−0.70	64.04
N′-Sto	−0.22	+1.47	+0.42	−0.97	86.78
Depth					
Ss-Pmp	−4.99^{xxx}	−4.20^{xxx}	−3.21^{xx}	−4.26^{xxx}	53.08
Sp-Pmp^{ˇ}	−4.10^{xxx}	−3.19^{xxx}	−1.58	−4.22^{xxx}	57.38
Sp-K$^{+ˇ}$	−2.12^{xx}	−0.58	+0.31	−1.91^{xx}	31.96
K-Pmp	−2.14^{xxx}	−2.59^{xxx}	−1.87^{x}	−2.26^{xx}	25.40
Pmp-VL	+0.54	−1.15	+0.34	−2.57^{xxx}	13.46
Ptm-VL	+0.65	−0.85	−0.33	−2.00^{xxx}	13.66
[1]Pl-Pmp$^{ˇ-}$	1.69^{xx}	0.47	3.73^{xx}	0.97	0.68
Pmp-Ba	−1.98^{x}	−2.23^{x}	−2.69	−3.47^{xxx}	47.82
Position					
S-N-Rhi	−1.88	−3.38^{x}	−0.86	−6.23^{xxx}	115.26
S-N-Sp^{-}	−2.97^{x}	−3.31^{xx}	−0.35	−5.79^{xxx}	85.22
S-N-Ss	−3.49^{xx}	−3.96^{xxx}	−1.95	−5.28^{xxx}	80.68
S-N-Pr	−4.53^{xxx}	−4.81^{xxx}	−2.94^{xx}	−5.70^{xxx}	82.94
S-N-Zm	−1.34	−2.00^{x}	−0.31	−3.10^{xxx}	53.44
S-N-Or	−0.74	−1.61	+0.49	−1.89^{x}	54.58
[1]dev. Bsptn$^{-ˇ}$	−0.66^{x}	−0.55	+0.47	–	+0.13
[1]dev. Intis	+0.23	−0.17	+0.13	–	−0.02
Inclination					
PL/NSL	+0.32	+1.48	+0.65	−0.78	8.02
ISL/PL	−1.71	+1.20	−1.93	−8.10^{xxx}	92.26
ASL/PL	−2.76	−2.04	−2.47	−10.50^{xxx}	107.60

$^{+}$ Significant differences between complete and incomplete clefts
^{ˇ} Significant differences between complete clefts and soft palate clefts
$^{-}$ Significant differences between incomplete clefts and soft palate clefts
[1] In these characteristics the mean values are presented (+ = deviation to the right, − = deviation to the left)

similarities concerned the reduction of maxillary depth and deficient mandibular growth, while less important changes i.e. a shorter upper face, dentoalveolar retroinclination of the maxilla and a wider nasal cavity and interocular space were not present in an isolated cleft palate. The basic skeletal facial changes in an isolated cleft palate, i.e. retrusion of the upper and lower jaws, a flattened profile, disturbed sagittal and vertical maxillomandibular relations and limitation of anterior growth rotation

TABLE 3. Mandibular and Related Facial Dimensions in Different Cleft Types Compared to Controls (Explanatory Notes See Tab. 1)

Variable	CP_c	CP_i	CP_s	CLP_{uni}	*Control*
Size					
Pgn-Go	−0.49	−2.55^{xx}	−3.56^{x}	−2.79^{xx}	78.96
Cd-Go	−3.92^{xx}	−2.39^{x}	−2.62^{x}	−2.40^{xx}	67.42
Ii-Gn	+0.97	+1.19	+0.02	+2.12^{xx}	45.94
Go-Go	−0.86	−0.21	−1.68	−0.94	112.55
Ag-Ag	+0.55	+0.62	−0.91	+1.68	98.04
Shape					
ML/RL	+5.82^{xxx}	+7.63^{xxx}	+2.51	+6.82^{xxx}	121.96
CL/ML	−8.98^{xxx}	−7.13^{xxx}	−5.69^{xx}	−6.10^{xxx}	70.76
Position					
S-N-Sm	−1.20	−2.29^{x}	−1.60	−2.25^{xx}	78.20
S-N-Id	−1.83	−2.58^{x}	−2.35^{x}	−2.53^{xx}	80.08
S-N-Pg	−0.62	−2.00^{x}	−1.31	−2.10^{x}	79.84
N-S-Cd	−2.24	−0.77	−3.41	−0.25	131.08
Cd-NSL	+0.53	+0.12	+1.44	−0.05	19.16
Ar-tGo	−4.40^{xxx}	−3.37^{xx}	−2.77^{x}	−3.65^{xxx}	57.84
Go-VL	−1.36	−0.42	−0.10	+0.44	17.70
[1]dev.Id	−0.39	−0.23	+0.20	+0.20	−0.10
[1]dev.Gn	−0.22	−0.03	−0.13	−0.12	−0.18
Inclination					
RL/NSL	−0.78	−0.72	+0.71	−0.09	88.16
ML/NSL	+5.16^{xx}	+7.07^{xxx}	+3.40	+6.75^{xxx}	30.06
IIL/ML	−13.30^{xxx}	−10.35^{xxx}	−7.06^{x}	−11.92^{xxx}	79.56
IIL/NSL	+7.54^{xx}	+2.77	+3.08	+4.62^{xx}	70.78
N-S-Pgn	+0.93	+2.77^{xx}	+1.65	+2.83^{xxx}	68.48
Face as a whole					
N-Gn	+1.50	+4.12^{x}	+0.71	+3.46^{x}	130.16
N′-Pg′	+1.68	+4.40^{xx}	+2.15	+2.03	120.38
Sp-Pg^{+}	+0.81	+3.93^{xx}	+1.07	+5.48^{xxx}	67.66
S-Go	−3.44^{x}	−1.88	−0.83	−2.08^{x}	88.10
S-Pgn	+0.28	+1.25	−1.29	+0.06	135.56
Pr-Id	+1.20^{x}	+1.92^{xxx}	+1.10	+2.18^{xxx}	21.30

$^{+}$ Significant differences between complete and incomplete clefts

[1] In these characteristics the mean values are presented (+ = deviation to the right, − = deviation to the left)

during the development of the face, were identical with those encountered in unilateral cleft lip and palate. Thus the configuration of the main facial skeletal characteristics was highly similar in both types of clefts (Figure 5). Obviously, a more favourable situation was present in cleft soft palate alone (Figure 6) because of the less marked retrusion of the maxilla, while the growth deficiency of the mandible was even more pronounced. The slighter retrusion of the maxilla represented most probably the result of a less extensive surgical procedure, as well as of the greater resistance of the upper jaw, with an intact hard palate, to the secondary effects of surgical repairs.

The reason that isolated cleft palate was not associated with an impaired vertical growth of the upper face or with a retroinclination of upper incisors and of the alveolar process was easily understood. In cleft palate the situation is similar to incomplete cleft lip and palate where the continuity of the alveolar arch is partly maintained as well (Šmahel and Brejcha, 1983). The presence of this continuity is essential for the vertical growth of the upper face. As well, the dentoalveolar component of the upper jaw is not exposed to increased tension exerted by the lip after its repair which results in retroinclination.

There was no increase in the interorbital

TABLE 4. Facial Profile Dimensions in Different Cleft Types Compared to Controls (Explanatory Notes See Tab. 1)

Variable	CP_c	CP_i	CP_s	CLP_{uni}	*Control*
Height and depth					
Sn-Ls	−0.25	+0.28	+0.07	-2.35^{xxx}	17.66
Sn-Sto+	−1.12	+0.38	−0.14	-1.97^{xxx}	24.34
Prn-Sn	−0.81	−0.69	−0.40	−0.52	20.00
Prn-Spˇ	+0.26	−0.05	-1.50^{x}	-2.77^{xxx}	32.30
Thickness					
Ss'_t ˇˇˇ ¯¯¯	$+2.68^{xxx}$	-2.98^{xxx}	+0.47	-0.75^{x}	14.80
Pr'_t ˇˇˇ ¯¯	$+3.08^{xxx}$	$+2.62^{xxx}$	+0.67	-0.78^{x}	15.26
Id_t ˇˇ	$+1.31^{xxx}$	+0.71	+0.07	−0.22	11.60
$Sm\text{-}'_t$ ˇˇˇ ¯	$+1.40^{xxx}$	$+0.80^{x}$	−0.19	−0.24	12.26
Pg'_t	+0.60	−0.18	−0.61	−0.09	14.68
Facial convexity					
N-Ss-Pgˇ	$+5.85^{xxx}$	$+4.16^{xx}$	+1.08	$+5.79^{xxx}$	178.12
N′-Sn-Pg′	$+3.36^{x}$	+1.20	−0.31	$+10.34^{xxx}$	164.64
N′-Prn-Pg′	$+3.72^{xx}$	$+2.53^{x}$	+0.80	$+9.29^{xxx}$	134.00
Jaw position					
S-N′-Ss′	-2.17^{x}	-2.58^{x}	-2.75^{x}	-6.36^{xxx}	87.08
S-N′-Sm′	−0.33	−1.76	−1.72	-2.20^{xx}	79.92
S-N′-Pg′	−0.53	-2.31^{x}	−1.74	-2.32^{xx}	82.34
Jaw relations					
Ss-N-Smˇ	-2.29^{xxx}	-1.67^{xx}	−0.35	-3.03^{xxx}	2.48
Ss-N-Pgˇ	-3.07^{xxx}	-2.20^{xx}	−0.84	-3.22^{xxx}	0.84
ML/PL	$+4.84^{x}$	$+5.59^{xxx}$	+2.76	7.53^{xxx}	22.04
Ss′-N′-Sm′	-1.85^{xxx}	−0.82	−1.03	-4.16^{xxx}	7.16
Ss′-N′-Pg′	-1.65^{x}	−0.27	−1.01	-4.03^{xxx}	4.74

+ Significant differences between complete and incomplete clefts

ˇ Significant differences between complete clefts and soft palate clefts

¯ Significant differences between incomplete clefts and soft palate clefts

[1] In these characteristics the mean values are presented (+ = deviation to the right, − = deviation to the left)

distance, nor changes in the proportional relationships within this region. A slightly wider nasal cavity in complete clefts could be suggestive of the original cleavage of the cavity. The smaller width of the alveolar arch at its base could reflect secondary transverse narrowing.

Changes of the mandibular shape represented an adaptation to the deficient growth which could be partially of a primary origin. This assumption was based on results obtained in experimental animals which provided evidence that an isolated cleft palate could be induced during embryonal life by the deficient growth of the mandibular anlage during the third critical period (Jelínek and Peterka 1977, Diewert 1979). So far it has not been demonstrated that this mechanism causes the development of these malformations in humans as well. Our results confirm the presence of a deficient mandibular growth and therefore could be suggestive of this mechanism.

A comparison of the results obtained in individual subgroups of isolated cleft palate revealed that the less extensive the cleft, the smaller the mandible. This could be explained by the etiopathogenesis of the malformation. Experimental studies showed that the slighter the degree of isolated cleft palate, the more delayed was its induction during the embryonal development and that it required a more potent teratogenic agent (Jelínek et al. 1983). Cleft of the soft palate developed at a time when the palatal plates were almost fused and thus all morphologic prerequisites required for the normal development of the palate were provided. At this time the malformation could be induced only by a strong impetus. More extensive mandibular changes could be expected in the case of a

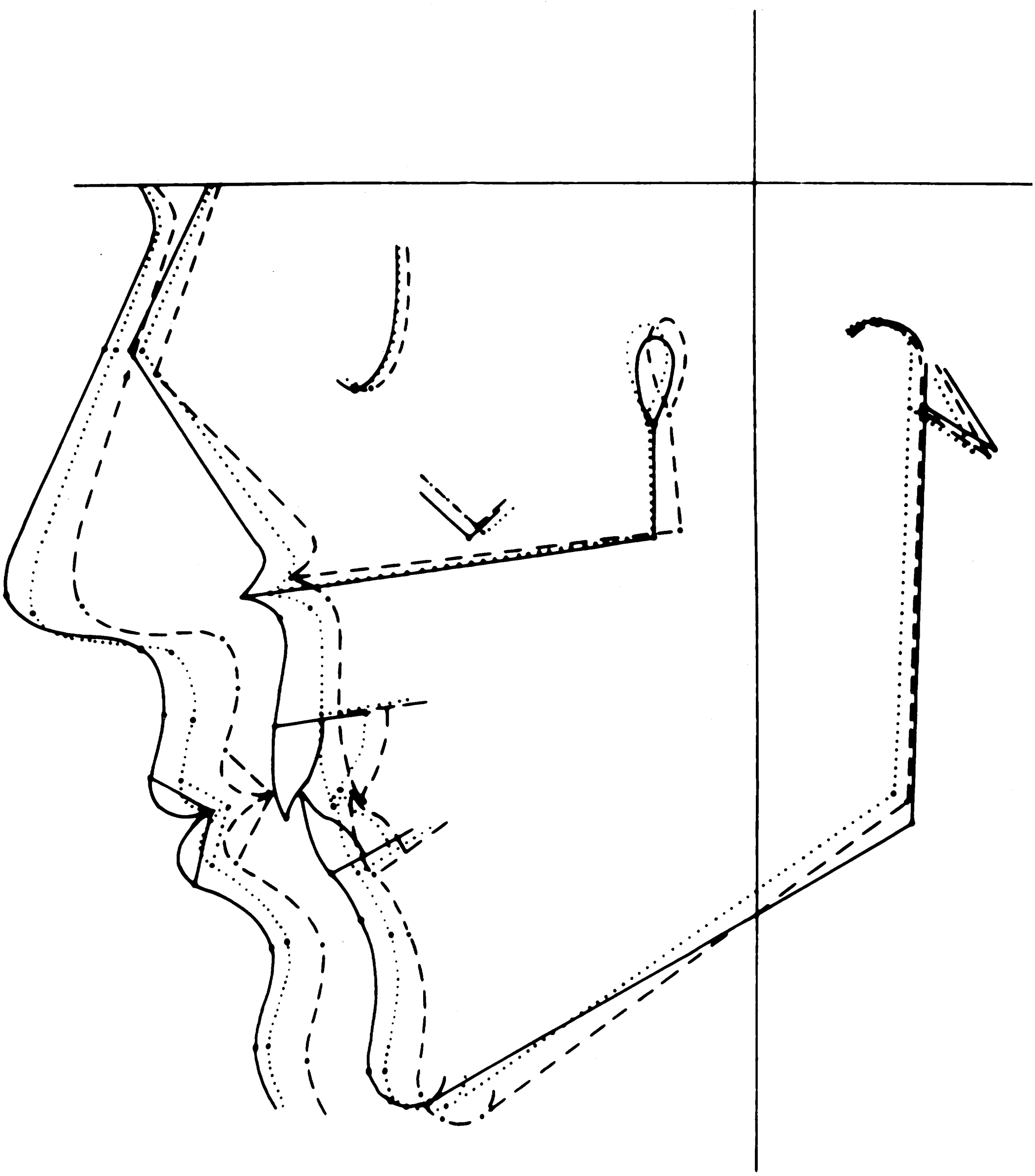

FIGURE 4. Faciograms in lateral projection (solid line = controls, interrupted line = unilateral cleft lip and palate, dotted line = complete cleft palate, CP_c).

primary damage. This assumption was also in agreement with our results. However a complete cleft palate did not develop during the third critical period and was induced earlier at a time when the above mentioned mechanism of action did not operate in the induction of the malformation (Jelínek et al. 1983). This was in agreement with the absence of mandibular shortening. This concept is based on experimental studies in which clefts were induced by teratogens, i.e. by exogenic factors. Since our clinical findings were in good agreement with experimental observations, as well as with the assumptions derived from the latter, it could be postulated that exogenous factors played an essential role in the etiology of clefts in humans as well, both in the presence or absence of a genetic predisposition. This is favorable for preventive measures.

According to the above mentioned hy-

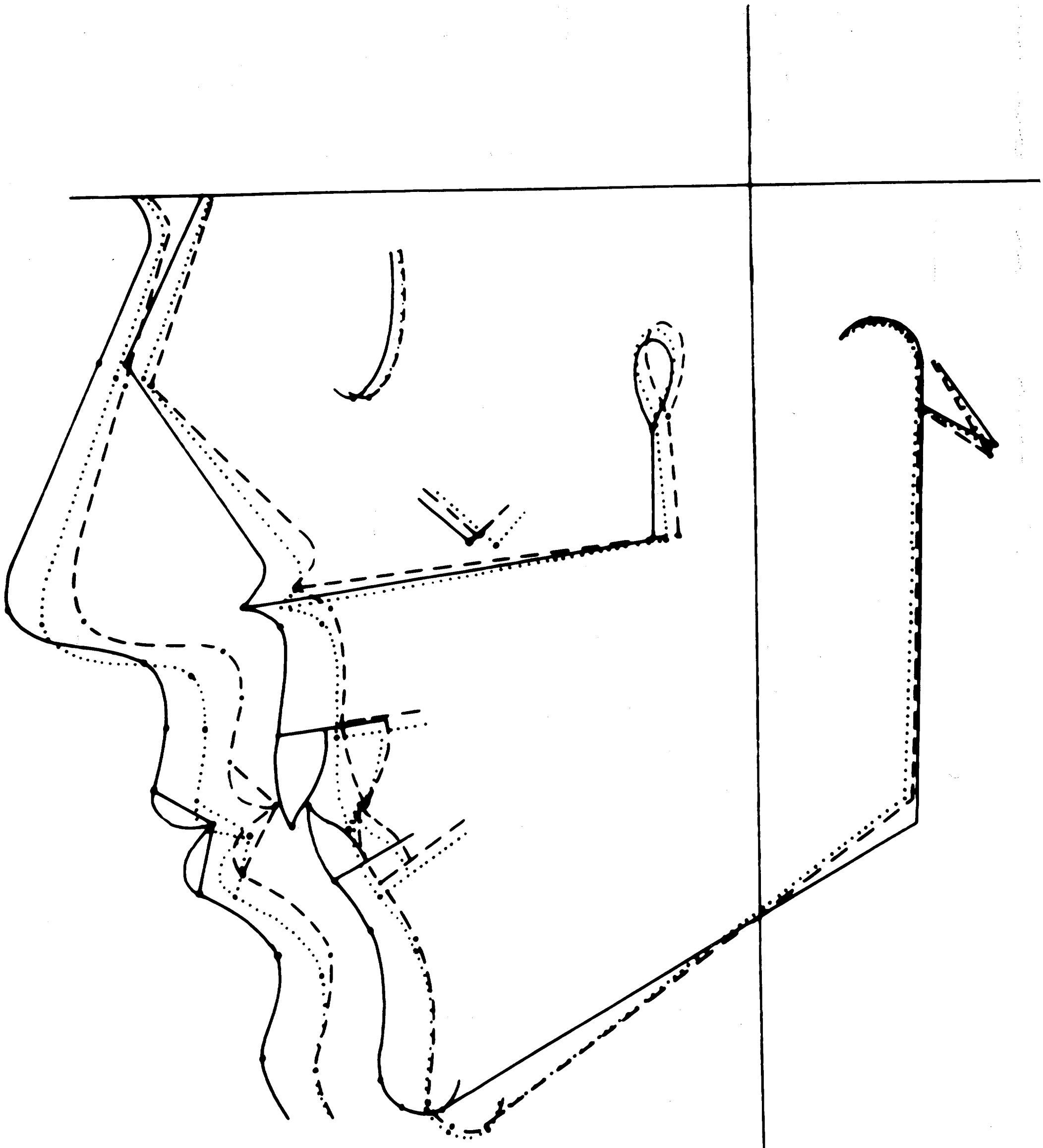

FIGURE 5. Faciograms in lateral projection (solid line = controls, interrupted line = CLP_{uni}, dotted line = incomplete cleft palate, CP_i).

pothesis it would be possible to expect a negative correlation between the extent of cleft palate and changes which were at least partially primary in origin. However in the region of the upper jaw secondary postoperative changes, which are of major importance, were less marked in cleft soft palate, and the maxilla was less affected in this subgroup. The comparison of the two other subgroups revealed a higher degree of deviation in incomplete cleft palate, which was in agreement with the above hypothesis. This finding showed that it should be expected that the orthodontic treatment of this type of cleft could be associated with greater difficulties, since it was accompanied by a high degree of retrusion of the maxilla and by the highest frequency of impaired occlusion in the anterior segment of the denture. This was in

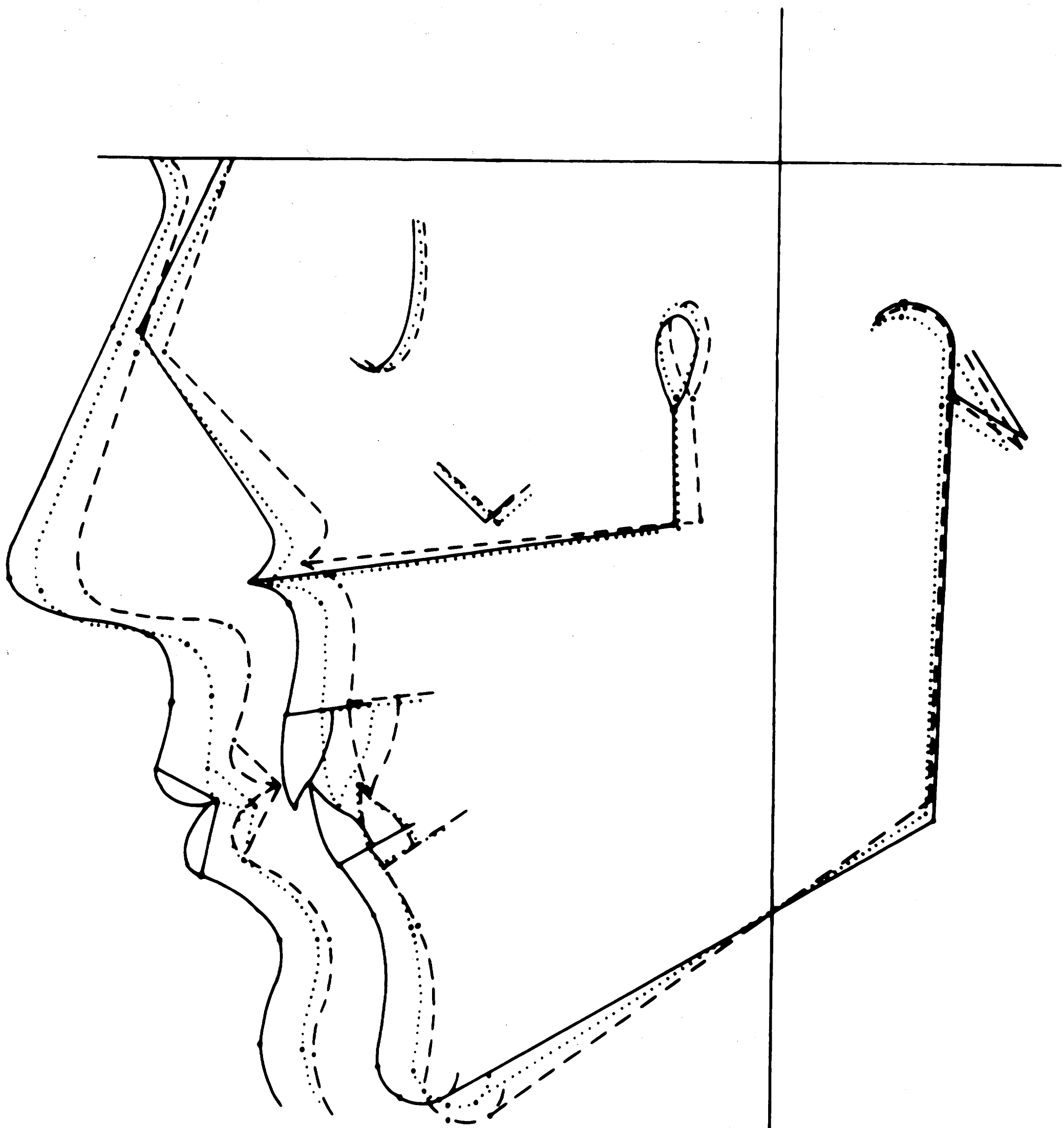

FIGURE 6. Faciograms in lateral projection (solid line = controls, interrupted line = CLP_{uni}, dotted line = cleft of the soft palate, CP_i).

agreement with the findings reported by Brousilová and Brousil (1977). A similar relationship was apparent also in basic somatometric characteristics (Šmahel, 1983). The above findings were in agreement with the fact that these individuals were exposed to a stronger teratogenic impetus as compared to individuals with complete clefts.

Contrary to cleft lip and palate where, because of the reduced thickness of the upper lip, the profile was even flatter than the skeletal profile of the face (Šmahel and Brejcha, 1984), in an isolated cleft palate changes of the skeletal profile were to a large degree masked by soft tissues. In soft palate clefts however, the soft tissue profile was more markedly deviated from the norm than in clefts of the hard palate. This was confirmed by the lateral facial dimensions (Šmahel, 1983). Certain changes of

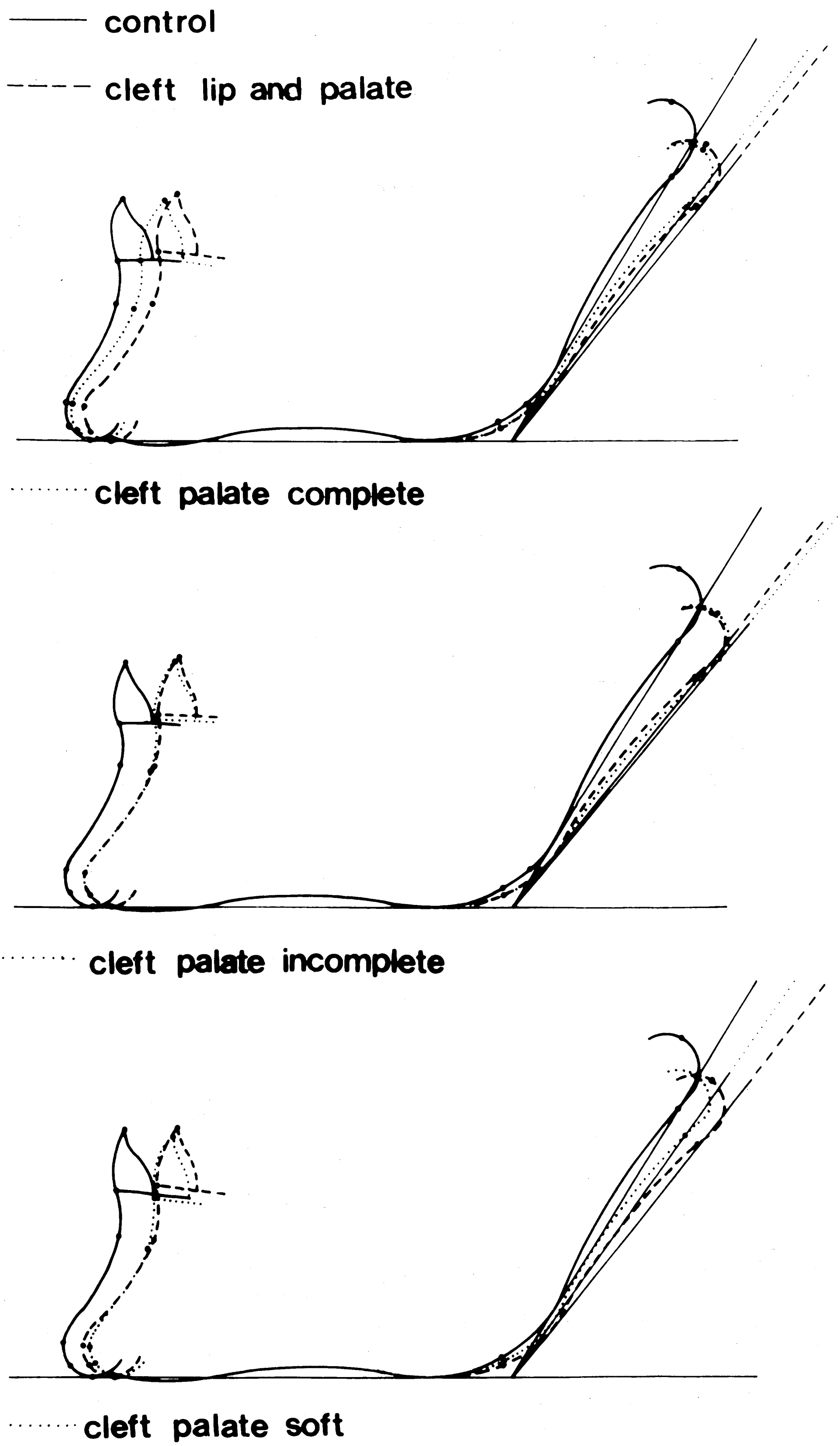

FIGURE 7. Morphograms of the mandible.

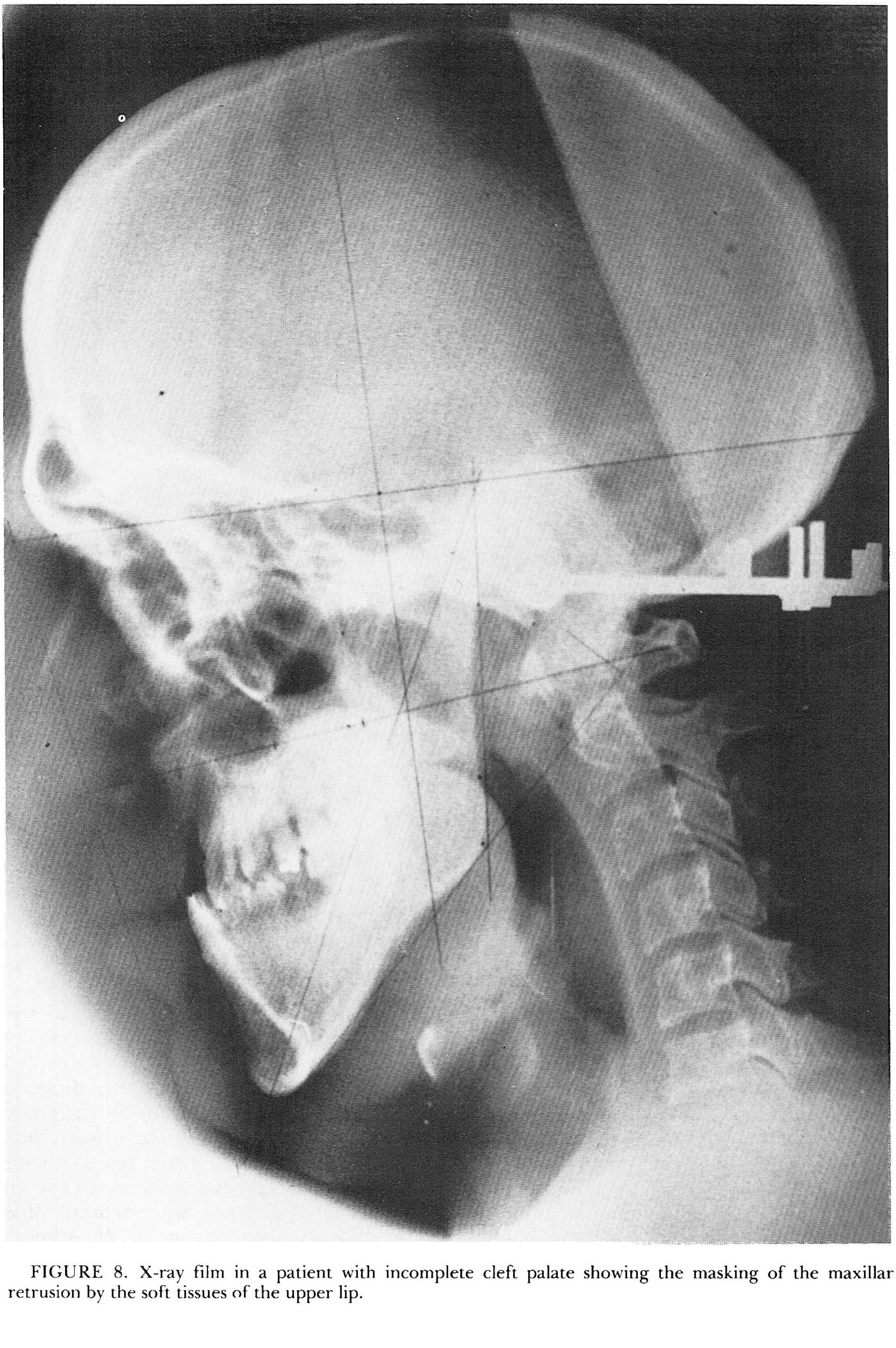

FIGURE 8. X-ray film in a patient with incomplete cleft palate showing the masking of the maxillar retrusion by the soft tissues of the upper lip.

facial physiognomy were generally recorded in isolated cleft palate during visual inspection and it might be possible that they were most spectacular in cleft soft palate. This problem was discussed in more detail in the first part of our study (Šmahel, 1983).

The posterior displacement of the maxilla was sometimes considered as the sequelae of retroposition and pharyngofixation. This hypothesis was not confirmed in our studies, since it was not demonstrated in our series. The causes of the other reported changes were discussed in our earlier paper (Šmahel and Brejcha, 1984). The length of the nose was in good correlation with the length of nasal bones (in controls $r = 0.605$, $p < 0.001$) and thus also with the retrusion of the maxilla ($r = 0.322$, $p < 0.05$). Therefore clefts were associated sometimes with a slight prolongation of the nose (see CP_i). This could provide an explanation of the findings reported by Sadowsky et al. (1973).

Differences between the terminal part of the palate (Pl-Pmp), yielded maximum values in soft palate clefts and differed significantly from those in the other subgroups and in controls. This illustrated that soft palate clefts were associated frequently with a shorter and thus not completely intact hard palate.

As in one of our previous papers (Šmahel and Brejcha, 1983), linear regression was used for the evaluation of the relation between the depth of the maxilla and the mandibular angle (Figure 9). While in the subgroup with complete clefts ($r = -0.522$) the relation was similar to controls ($r = -0.278$, $t = 1.24$) there were differences in incomplete clefts ($r = 0.027$) and in soft palate clefts ($r = 0.087$). The differences between the correlation coefficients both for CP_c and CP_i ($t = 2.31$, $p < 0.025$) and CP_c and CP_s ($t = 2.05$, $p < 0.05$) were significant (tested after z-transformation). Thus in isolated cleft palate the growth of the lower jaw was not sufficiently potent and therefore could not proceed according to the normal developmental pattern. Therefore the adaptation of the mandible to the greater depth of the maxilla leads to the formation of a more obtuse angle and not to the active growth recorded in controls. This could confirm the presence of a primary damage of mandibular growth potency. However the altered growth pattern did not apply to a complete cleft palate because of its differing pathogenetic background. This finding was in agreement with experimental knowledge. However, it was necessary to consider the possibility of much more complex and mediated relations, and to take into account that even a morphologically homogeneous group of clefts was induced always by a heterogeneous mechanisms. Therefore it appeared justified to assume the participation of further relations which might interfere with the investigated conceptions. Besides this, the lower jaw actually showed a marked developmental adaptability.

The higher frequency of anomalous cervical vertebrae in cleft palate was determined in 1965 by Ross and Lindsay. We failed to disclose this anomaly during the investigations of 60 patients with CLP_{uni}, and in 36 individuals with cleft lip alone.

The comparison of our results with those reported by some other authors disclosed some differences as well as similarities. The basic deviations, i.e. the shortening and retrusion of both jaws were in good agreement with the reported data for various age groups (Ross and Coupe 1965, Shibasaki and Ross 1969, Dahl 1970, Nakamura et al. 1972, Bishara and Iversen 1974, Bishara and Tharp 1977, Cronin and Hunter 1980). We failed to reveal any essential differences in the configuration of the cranial base, agreeing with Ross (1965) and subsequently other authors (Ross and Coupe 1965, Shibasaki and Ross 1969, Bishara and Iversen 1974, Bishara and Tharp 1977). The shortening of the cranial base was noted by Dahl (1970), who also recorded an obtuse angle of the base. This was in agreement with the findings of Cronin and Hunter (1980). Deviations in the flexion of the cranial base were mentioned, sometimes, in other types of clefts as well (see Šmahel and Brejcha, 1984), but were not considered as essential (Ross 1965, Bishara and Iversen 1974). A height reduction and shortening of the neurocranium was ascertained in adult males by Dahl

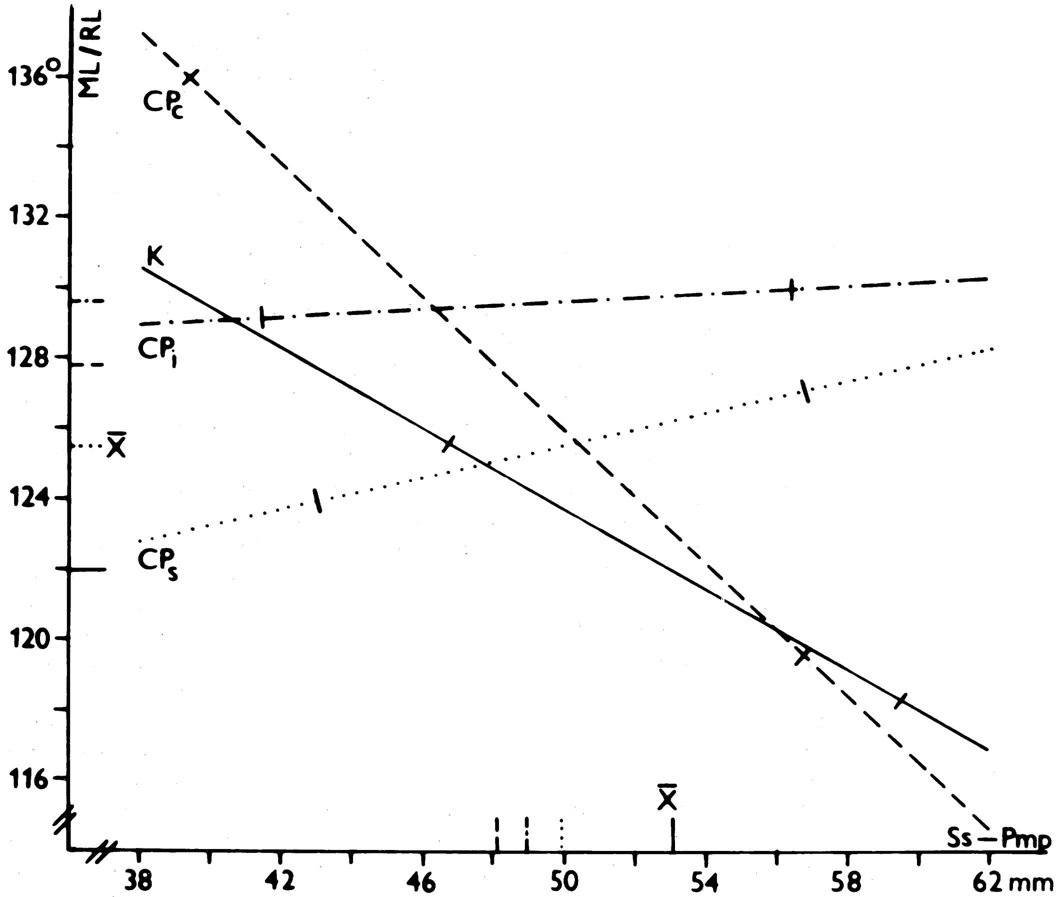

FIGURE 9. The relation between maxillar depth (Ss-Pmp) and the mandibular angle (ML/RL) expressed in terms of linear regression (K = control, CP_c = complete cleft palate, CP_i = incomplete cleft palate, CP_s = cleft of the soft palate; abscissa on the straight line = $\overline{X} \pm 2$ SD of the maxillar depth).

(1970), although we failed to confirm the latter (our population was brachycephalic).

It was possible to compare our results with those obtained by Dahl (1970) in adult males with isolated cleft palate. The facial changes reported were identical with those recorded in our series, inclusive of the persisting overbite, yet with the exception of the supraposition of the mandibular joint, the reduction of the posterior height of the upper face associated with retroinclination of the palate plane, a posterior displacement of the maxilla (Pmp-VL) and a somewhat more oblique slope of the mandibular body. The first deviation mentioned was open to controversy in the literature (Šmahel and Brejcha, 1984), while the latter deviation was rather uncommon. Up to the present time no agreement was reached on the reduction of the posterior height of the upper face or on the displacement of the maxilla backwards in an isolated cleft palate. The two latter deviations were demonstrated in children by Cronin and Hunter (1980), while Shibasaki and Ross (1969) failed to ascertain a significant maxillary displacement backwards. Some differences could be related to the age of the individuals examined.

As compared to cleft lip and palate (CLP_{uni}) the substantial differences included in an isolated cleft palate the absence of an impairment of upper face vertical growth, as confirmed for the anterior height by Shibasaki and Ross (1969), Dahl (1970), Bishara and Tharp (1977) and by Cronin and Hunter (1980), unchanged inclination of upper incisors demonstrated by

Dahl (1970) and by Bishara and Tharp (1977), as well as the unchanged interorbital distance documented by Dahl (1970), Aduss et al. (1971) and Hirschfeld and Aduss (1974). A significant deviation in etiopathogenetic view represented the shortening of the mandible. Ross and Coupe (1965) and Cronin and Hunter (1980) disclosed that it was even greater in an isolated cleft palate than in cleft lip and palate. A reduction of the mandible in cleft palates was demonstrated by Nakamura et al. (1972) as early as in childhood. These findings were consistent with the conception of a primary damage. An obtuse gonial angle and a steeper slope of the mandibular body resulting from the shortening of the ramus (they were described by Shibasaki and Ross 1969, Dahl 1970, Bishara and Tharp 1977, Cronin and Hunter 1980). These changes were associated with the posterior rotation of the face described by the above authors, as well as by Ross and Coupe (1965). It was related to the reduction of the posterior height and the increase of the anterior height of the face, though both of them commonly did not attain the significance level (Bishara and Tharp 1977, Cronin and Hunter 1980, or in posterior height also Shibasaki and Ross 1969). This was in agreement with our conclusions and was related to the extent of the cleft (a significant increase of the anterior height at the level of $p < 0.05$ was recorded by Shibasaki and Ross 1969, and by Dahl 1970). In agreement with other investigators (Shibasaki and Ross 1969, Dahl 1970, Bishara and Iversen 1974, Bishara and Tharp 1977) the impairment of maxillomandibular relations was slighter than that associated with cleft lip and palate. No data were found in the available literature on the masking of the facial skeletal flattening by soft tissues.

The relationship between the growth deviations and the extent of the cleft palate was investigated by Dahl (1970) and Bishara (1973). Both authors mentioned a significantly smaller shortening of maxillary depth and a slighter retroinclination of lower incisors in soft palate clefts as compared with more severe clefts. Both findings were confirmed by our results. Dahl (1970) found in both subgroups an identical shortening of the mandible, yet a slighter obliquity of the body and with less posterior rotation in soft palate clefts resulted in a less retrognathic mandible in this type of cleft. These results were in agreement with our findings during the comparison with data obtained in complete clefts (which were most frequent in the series reported by Dahl as well). No other reports on this topic were found in the literature.

Our findings disclosed that the extent of cleft palate exerted an effect on some parameters of the craniofacial skeleton. Even though the differences between individual subgroups did not attain regularly the significance level, they were obvious and sometimes exceeded those ascertained during the comparison with the group of controls (N-Gn, S-Go, Pgn-Go, VL/ML, IIL/NSL, S-N-Ss, S-N-Pg, N′-Pg′, S-N′-Pg′ a.o.). This was due to small numbers of cases in CP_s and to the larger variability of deviated characteristics. Thus it represented only the result of the statistical analysis. This should be kept in mind in order to avoid an underestimation of the biological significance of these findings. From this follows that during the comparison of individual series due regard should be paid to their compositon and to the extent of cleft palate.

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