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ORIGINAL ARTICLE

Inclination of the infraorbital canal studied on dry skulls expresses the maxillary growth pattern: a new contribution to the understanding of change in inclination of ectopic canines during puberty

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Abstract

Objective. The purpose of this study was to analyze the correlation between direction of the infraorbital canal and maxillary width on frontal radiographs of dry human skulls. ***Material and methods.*** Forty-two symmetrical, dry human skulls (late adolescence and adult) with no dental or skeletal anomalies. Frontal radiographs were taken of each skull placed in the Frankfort horizontal plane, with a radiopaque marker in the infraorbital canal. The maxillary transversal growth pattern was expressed as the infraorbital transversal angle (IOt) formed between a line through the contour of the bilateral orbita (lo) and a line parallel to the infraorbital marker. Three cephalometric widths were measured on the skulls, two anteriorly (the width of the piriform aperture (AP) and the interorbital width (IO)) and one posteriorly (the palatal width (PW)). A general linear model was used for statistical analysis. ***Results.*** The direction of the infraorbital canal (66.08°, 95% CI: 62.53–69.64) depended on the transversal growth: an increased PW of 1 mm resulted in a decreased IOt of 1.84° ($p = 0.041$); an increase in IO of 1 mm resulted in an increased IOt of 2.24° ($p = 0.017$); and an increased AP of 1 mm resulted in a decreased IOt of 3.30° ($p = 0.066$). ***Conclusions.*** The study indicates that the direction of the infraorbital canal in frontal view reflects the transversal growth of the maxilla. A wide maxilla posteriorly resulted in a small infraorbital transversal angle. These findings might explain the different inclination of ectopic canines.

Key Words: *Anthropology, growth, infraorbital, maxilla, nerve canal*

Introduction

The growth pattern of the maxilla and mandible has been explained by Björk [1,2] and Björk & Skieller [3,4], who, in cephalometric studies with fixed bone markers, have shown that the mandibular and pterygomaxillary canals are stable structures during growth. Both canals are present at birth, but elongate gradually through postnatal growth, which means that these structures are suitable as superposing radiographic structures in craniofacial growth analysis [4,5].

Furthermore, Pálsson & Kjær [6] demonstrated that the direction of the mental canal on dry skulls is closely associated with the shape of the mandibular canal. The process of initial formation of the mental foramen encircling the mental nerve has been described prenatally [7]. It is assumed that the mental canal develops gradually by apposition buccally on the corpus of the mandible. Pálsson & Kjær [6] demonstrated a close relationship between mandibular morphology and direction of the mental canal. This means that the mental canal expresses the direction of the mandibular growth in the condyle and the growth by bone apposition on the corpus of the mandible.

Formation of the infraorbital canal encircling the maxillary nerve starts from an early prenatal infraorbital foramen [8], which gradually develops into a canal, encircling the maxillary nerve, due to apposition mainly in the lower aspect of the ocular cavity. The infraorbital foramen develops at the 10th week of gestation [8]; the transition from a foramen to a canal takes place later in prenatal life and postnatally during maxillary growth in the vertical, sagittal, and transverse direction.

Many studies have focused on the postnatal anatomic characteristics of the infraorbital foramen [9,10] and also specifically on the location of the foramen in human skulls [11–13]. The infraorbital

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canal and its relation to the median plane have also been described by Lee et al. [14].

Transverse growth of the palate occurs in the median palatine suture and by apposition [4,15]. Studies have documented that the transversal growth is not uniform, with more intensive growth posteriorly than anteriorly [3,15,16]. Growth of the maxilla varies in different individuals and results in a range of widths of the maxillary dental arch, which causes divergent skeletal transversal malocclusions.

The hypothesis of the present study is that the inclination of the infraorbital canal compared to a horizontal plane is different in narrow and wide maxillae, and that the direction of the infraorbital canal might express the differentiated transversal maxillary growth. The purpose of the present study was to analyze the correlation between the direction of the infraorbital canal and the anterior and posterior maxillary widths on frontal radiographs of dry human skulls.

Material and methods

Skulls

Forty-two symmetrical, dry, human skulls with no dental or skeletal anomalies, from late adolescence and adult period, were analyzed. The skulls were from a collection of normal and pathological skulls at the Department of Orthodontics, Copenhagen School of Dentistry, Denmark.

Registration of the infraorbital canal

A radiopaque pin as thick as the infraorbital canal was placed as a marker in the right infraorbital foramen of each skull. The pin's thickness ensured stability in the canal (Figure 1).

Radiography

Frontal posterior anterior radiographs were taken of each skull, with the infraorbital marker in the right infraorbital canal. The radiographs were taken at the Department of Orthodontics, School of Dentistry, Copenhagen, using a Philips/Valmet BR 2002 cephalostat (Tagarno A/S, Horsens, Denmark) with a film focus distance of 195 cm. The linear enlargement was 8.3 percent. The radiographic film used was LifeRay XDA Plus UTLG (Ferrania Technologies, Cairo Montenotte, Italy) exposed with 65–67 kV and 5–7 mA. The radiographs were taken with the skulls placed in front of the film in the Frankfort horizontal plane.

Cephalometric analysis of the infraorbital canal

Tracing paper was placed on each posterior anterior (PA) radiograph and the outer contour of the skull, the orbitae, the piriform aperture, the innominate line and line 1, which connects the two bilateral orbita points (lo), were drawn with a pencil (line 1; Figure 2). The bilaterals were defined according to Svanholt & Solow [17]. The metal marker indicating the direction of the infraorbital canal was also marked on the tracing paper (line 2; Figure 2) and the direction of the infraorbital canal was expressed as the infraorbital transversal angle (IOt) between lines 1 and 2 (Figure 2).

Figure 1. Frontal view of a cranium with a metal pin in the right infraorbital canal.

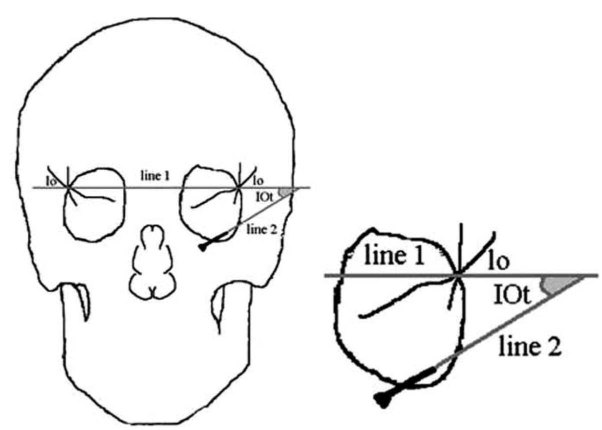

Figure 2. Tracing on the posterior anterior (PA) cephalometric film of a normal human adult anthropological cranium (frontal view). Line 1 runs through the contour of the bilateral orbita points (lo), while line 2 is the direction of the infraorbital canal. The intersection between lines 1 and 2 forms the infraorbital transversal angle (IOt), which is the inclination of the infraorbital canal.

Cephalometric analyses of the widths expressing the maxillary growth

Three widths (two anterior and one posterior) were analyzed on the skulls:

- Piriform aperture width (AP): The width of the piriform aperture at the top of the inferior nasal conchae, anterior width (Figure 3).
- Interorbital width (IO): The distance between the left and right infraorbital foramen, anterior width (Figure 3).
- Palatal width (PW): Expressed as the maxillary cross-arch transversal palatal width (from first maxillary molar (left) to first maxillary molar (right), posterior width (Figure 4).

Statistical analysis

A general linear model was used for statistical analysis. IOt was the dependent variable and AP, PW and IO the explanatory variables. The mean level has been subtracted for all explanatory variables. The results are presented by p-values and the estimates with 95% confidence interval (CI). All explanatory variables were done using SAS (version 9.1, SAS Institute Inc., Cary, N.C., USA). P-values less than 5% were considered significant.

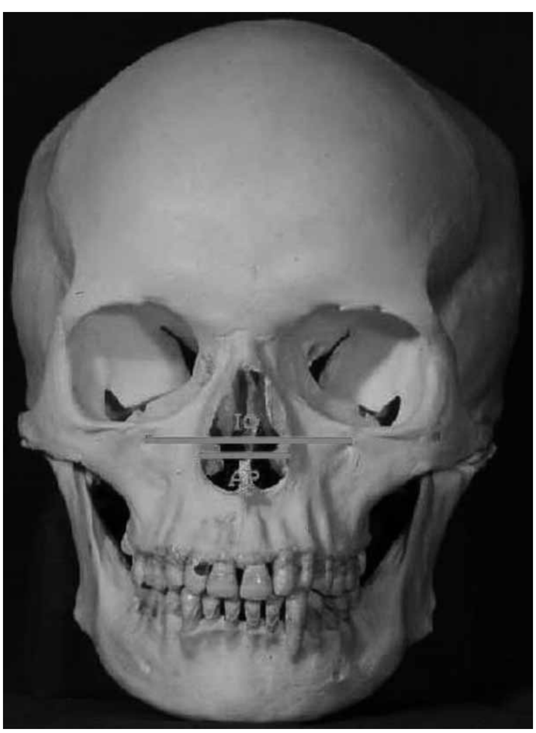

Figure 3. A cranium in frontal view. The measured interorbital (IO) and piriform aperture (AP) widths are shown by a red line on the picture. These distances express anterior maxillary widths.

Figure 4. The external cranial base and the maxilla in caudal view. The palatal width (PW) is indicated by a red line on the figure.

Results

Correlation between the dependent and explanatory variables

The measurements of the four variables are given in Table I. There was a strong correlation between the explanatory variables, but not between the dependent variable and the explanatory variables (Table II).

Using the linear model and including all explanatory variables revealed a statistically significant association between the explanatory variables and the dependent variable (results given in Table III). Table III illustrates statistical results from a cranium with the IOt mean value, 66.08°, with a 95% CI: 62.53–69.64. The table indicates that an increase in the palatal width (PW) of 1 mm resulted in a statistically significant decrease in the infraorbital transversal angle (IOt) of 1.84° ($p < 0.05$). The table also shows that an increase in interorbital width (IO) of 1 mm resulted in a statistically significant increase in the infraorbital transversal angle (IOt) of 2.24° ($p < 0.05$). Lastly, an increase in the piriform aperture width (AP) of 1 mm resulted in a non-significant decrease in the infraorbital transversal angle (IOt) of 3.30° ($p > 0.05$).

Discussion

The aim of the present study was to investigate the correlation between the direction of the infraorbital canal and the morphology of the maxilla on frontal radiographs of dry human skulls. A metal pin was

Table I. Descriptive statistic of the four variables.

Variable	n	Mean	SD	Minimum	Maximum
IOt_degrees	42	66.08	12.11	38.50	96.50
AP_mm	42	23.72	1.90	18.60	28.80
PW_mm	42	37.42	2.85	29.20	43.00
IO_mm	42	51.79	4.13	38.00	59.80

The four variables: IOt = infraorbita transversal angle, AP = piriform aperture, PW = palatal width, IO = interorbital width.

placed in the canal, and the angle between this pin and a line through the lateral orbitae expressed the infraorbital transversal angle (IOt). The pin illustrating the canal direction can be difficult to place depending on the form of the canal (oval, round, or semi-lunar) [9,10].

The present study demonstrates that the direction of the canal is different in maxillas with different transversal dimensions, which suggests that the canal direction might change in a longitudinal perspective during transversal growth, when the growth is differentiated with most growth activity posteriorly [3,15,16]. This is a new finding.

A previous study has shown that patients with palatally located ectopic maxillary canines have adequate maxillary dental arch width [18]. Meanwhile, a reduced transversal dimension in these cases has also been reported [19].

As ectopic canines evaluated on orthopantomograms have an inclination in the maxilla comparable to the inclination of the infraorbital canal studied on frontal radiographs, it is suggested that change in inclination of ectopic canines during puberty is caused by active transversal growth in the mid-palatal suture.

Divergent information on the maxillary transversal growth in these cases [18–22] might influence the change in inclination of an ectopic maxillary canine during puberty.

The sagittal and vertical growth might also interfere with the change in direction of the infraorbital canal, but in the present study only the frontal view was in focus, because ectopic canines are studied on orthopantomograms, where the dentition is looked at in the frontal aspect.

Table II. Correlation of the four variables by Pearson correlation efficients: Pearson Correlation Coefficients, N = 42; Prob > |r| under H0: Rho = 0.

	IOt_degrees	AP_mm	PW_mm	IO_mm
IOt_degrees	1.000	−0.14	−0.21	0.02
		0.39	0.17	0.88
AP_mm	−0.14	1.000	0.60	0.84
	0.39		<.0001	<.0001
PW_mm	−0.21	0.60	1.000	0.70
	0.17	<.0001		<.0001
IO_mm	0.02	0.84	0.70	1.000
	0.88	<.0001	<.0001	

The table shows no strong correlation between the dependent variable and the explanatory variables, but a strong correlation between the explanatory variables.

The study set-up of using dry human skulls has advantages and disadvantages. It was possible to see the direction of the infraorbital canal on radiographs, because it was made visible by placing a radiopaque pin in the canal, but it was impossible to evaluate the sex and age precisely on the cranium. It was also a disadvantage that the canal direction could only be analyzed at one stage during development in each cranium (cross-sectional study). In a longitudinal study, it would have been possible to follow the canal direction along with growth in the maxilla. This might be possible to do by Cone Beam Computed Tomography (CBCT), but it still does not solve the problem that the infraorbital canal is not visible in its full extent in frontal view.

Apparently, there are no similar studies in the literature regarding the association between growth of the maxilla and direction of the infraorbital canal. In the mandible, Pálsson & Kjær [6] have shown that direction of the mental canal is closely associated with mandibular growth and morphology. This observation in the mandible is in accordance with the findings in the maxilla, where direction of the infraorbital canal was closely associated with growth and morphology of the maxilla.

As pointed out earlier, it has been shown that palatally located ectopic maxillary canines have adequate maxillary dental arch width [18]. It can be assumed that the change in maxillary canine inclination during growth in puberty is due to changes in transversal growth in the mid-palatal suture. In the present study, a change in the direction of the infraorbital canal was observed concurrently with increasing transpalatal width.

In conclusion, the findings of the present study indicate that direction of the infraorbital transversal canal in frontal view reflects transversal growth of the maxilla. A wide maxilla in the inter-molar region was associated with a small infraorbital transversal angle (IOt). This means that ectopic canines, which are located more or less with the same inclination as the infraorbital canal, can change direction in frontal view during pubertal transverse maxillary growth, and that this might be the reason for the registered change in canine direction, which has never been understood.

The fact that the AP width expressing the external nasal cavity width is not significantly correlated with

Table III. Estimate for the intercept and the three explanatory variables.

	Parameter	Estimate	Pr > |t|	95% confidence limits
Intercept	66.08	<0.0001	62.53	69.64
PW_mm1	−1.84	0.041*	−3.60	−0.08
IO_mm1	2.24	0.017*	0.43	4.04
AP_mm1	−3.30	0.066	−6.82	0.23

*Significants, $p < 0.005$.

IOt, such as the IO width expressing the width of the maxillary corpus, might be caused by local factors in the internal nasal cavity.

By combining the knowledge gained in the present study with the existing knowledge on ectopic canines, it seems possible to explain the former unexplainable change in canine direction during puberty. The study indicates the importance of measuring the transverse palatal distance in the maxilla for diagnostic and treatment planning in cases with ectopic canines.

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