ORIGINAL ARTICLE

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Skull thickness in patients with skeletal Class II and Class III malocclusions

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Structured Abstract

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Objectives – To measure skull thickness in a group of subjects with skeletal Class II and a group with skeletal Class III malocclusion and compare these results with a group with Class I occlusion.

Setting and Sample Population – Department of Orthodontics, School of Dentistry, University of Copenhagen. The Class II group comprised 25 females aged 17–42 (mean 26.0). The Class III group comprised 53 patients, 29 females aged 17–39 (mean 24.2) and 24 males aged 17–38 (mean 22.6). The control group comprised 39 subjects, 19 females and 20 males, aged 22–30, with a neutral occlusion and normal vertical and sagittal jaw relationship.

Material and Methods – The thickness of the frontal, parietal and occipital bones was measured on lateral radiographs of patients with skeletal Class II and Class III and compared with the control group. Method error ranged from 0.30 to 0.60 mm and reliability coefficients from 0.79 to 0.97. Unpaired *t*-tests were used for evaluating differences in thickness.

Results – Females with skeletal Class II malocclusion had a significantly thinner occipital bone and thicker frontal bones than the control females. Skull thickness in Class III malocclusion was comparable to the control group.

Conclusion – The most important outcome of this study was reduced skull thickness in the occipital area and thickening of the frontal bone in females with skeletal Class II malocclusion compared with females with Class I. Deviations in the theca cranii are thus associated with skeletal Class II malocclusions.

Key words: bone; cephalometry; human; skull thickness

Introduction

Thickness of the skull has been measured and analysed over the years in anthropological as well as in medical studies (1–4). Relationships between thickness and gender, general body build and ethnicity have been studied, though with conflicting results (3–12). The influence of pathological conditions on skull thickness has been discussed as well (6, 10, 13–15). Anthropologists have compared the thickness of pre-historic skulls with modern populations (13, 16, 17).

Among the pathological conditions demonstrating a general thickening of the skull compared with normal standards are acromegaly (18, 19),

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hyperostosis cranii *ex vacuo* (20–22) and sclerosing bone dysplasias (23). Williams syndrome is an example of a pathological condition with a local thickening of the skull (15). Axelsson et al. (15) found that the frontal and occipital bones are significantly thicker in patients with Williams syndrome compared with the control group. Hyperostosis frontalis interna is another example, where the thickening is localized to the inner table of the frontal bone (24–27).

The aetiology behind the pattern of cranial vault thickness in normal and pathological development has been discussed over the years. Liebermann (28) reported that the individual skull thickness could depend on the individual's level of exercise and therefore be closely linked to the circulating amount of growth hormone. Hyperostosis cranii *ex vacuo* is seen in children suffering from hydrocephalus treated with ventricular shunting (20–22). The intracranial hypotension is here assumed to be an aetiologically important factor, and the thickening of the cranium a compensatory mechanism. Wolf & Falsetti (21) have presented a case report in which three patients with severe brain atrophy had a corresponding severe skull thickening. Interestingly, they therefore suggest that there is a connection between dynamic changes in brain size and skull thickness.

Different methods have been used to measure human skull thickness. Anthropological material and biopsy samples from cadavers have been measured using a caliper (9–11, 17). Cephalometric measuring on X-rays has also been used in anthropologic and in clinical studies (1–4, 6–8, 15, 16).

The interrelationship between thickness of the skull and skeletal malocclusions has not been published until very recently. Jacobsen et al. (29) measured the thickness of the skull in patients with skeletal deep bite and compared this with a control group including 18 profile radiographs. They found that patients with this vertical malocclusion have a general thickening of the skull (29). Similar studies on other skeletal malocclusions have not previously been published.

In recent studies, deviations in cranial and spine morphology have been related to skeletal malocclusions. Thus, Alkofide (30) studied the size and shape of the sella turcica in skeletal Class II and skeletal Class III malocclusion and found that patients in Class II had a smaller sella turcica size. Recently, Sonnesen & Kjær (31–34) found that vertebral fusion in the cervical column morphology was more prevalent in the malocclusion groups compared with the control group. These studies also showed that there were different fusion patterns in the different malocclusion groups. Short nasal bone length has recently been found in females with skeletal Class II malocclusion, whereas this was not the case in Class III malocclusion (35). Based on this, it could be hypothesized that there is different skull thickness in skeletal Class II and Class III malocclusions.

Therefore, the aims of the present study were to measure the skull thickness in a group of subjects with skeletal Class II and a group of skeletal Class III malocclusion and compare these results with a group with Class I occlusion.

Material and methods

Malocclusion groups Class II and Class III

The skeletal Class II malocclusion group included profile radiographs from 25 females aged 17–42 (mean 26.0). The skeletal Class III malocclusion group included profile radiographs from 53 patients, 29 females aged 17–39 (mean 24.2) and 24 males aged 17–38 (mean 22.6).

The inclusion criteria for the two groups of patients with severe skeletal malocclusions were: 1) adult patients aged between 17 and 42 years; 2) no history of orthodontic treatment during childhood; 3) sagittal jaw relationship (ANB angle) larger (Class II) or smaller (Class III) than one standard deviation, according to the cephalometric standard values described by Björk (36) assessed by profile radiographs of each individual; 4) at least 24 permanent teeth present; 5) no craniofacial anomalies or systemic muscle or joint disorders and 6) accessibility of a profile radiograph prior to presurgical orthodontic treatment.

All profile radiographs were selected from patients registered since 1975 in the orthodontic surgical patient archive (378 records) at the Department of Orthodontics, University of Copenhagen, Denmark. All patients fulfilling the criteria were included. The cephalometric mean values of the malocclusion groups are shown in Table 1.

Control group Class I

The control group comprised 39 subjects, 19 females and 20 males, all dental students aged 22–30 years,

Table 1. **Mean values and standard deviation (in parentheses) for the sagittal and vertical jaw relations, and the maxillary overjet and mandibular overbite in the groups**

Group	Sagittal jaw relation (ANB angle)	Vertical jaw relation (NL/ML angle)	Horizontal overjet (mm)	Vertical overbite (mm)
Class I	1.8° (1.7)	24.2° (2.9)	3.4 (0.9)	3.0 (1.2)
Class II	7.0° (2.4)	31.7° (8.1)	10.3 (3.5)	1.5 (5.9)
Class III	−7.8° (3.3)	25.5° (6.4)	−4.3 (2.3)	0.7 (3.0)

selected according to the below mentioned inclusion criteria, from material registered by Solow & Ingerslev (37, 38) between 1965 and 1975 at the Department of Orthodontics, University of Copenhagen, Denmark. The subjects in the control group were healthy Danish Caucasians with no prior history of orthodontic treatment or craniofacial anomalies. They had at least 24 permanent teeth present, neutral occlusion and normal vertical and sagittal jaw relationship diagnosed according to Björk (39). The cephalometric mean values of the control group are shown in Table 1.

Cephalometric methods

The profile radiographs were taken in a cephalostat with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. No correction was made for the constant linear enlargement of 5.6% (39).

The reference points for measuring the sagittal and vertical jaw relationship and the horizontal overjet and vertical overbite were defined according to Björk (40). The measurements of the thickness of the skull were defined according to Axelsson et al. (4). The thickness of the frontal bone, the parietal bone and the occipital bone were measured. In Fig. 1, the cephalometric reference points and lines necessary for measuring the skull thickness including the actual locations on the skull for measuring thickness are defined and marked.

The reliability of the variables describing the thickness of the frontal, parietal and occipital bones was assessed by remeasurement of 20 lateral radiographs selected at random from the previously recorded radiographs. The radiographs were measured again after 2 weeks, and the difference between the two sets of recordings were calculated. No significant differences between the two sets of recordings were found.

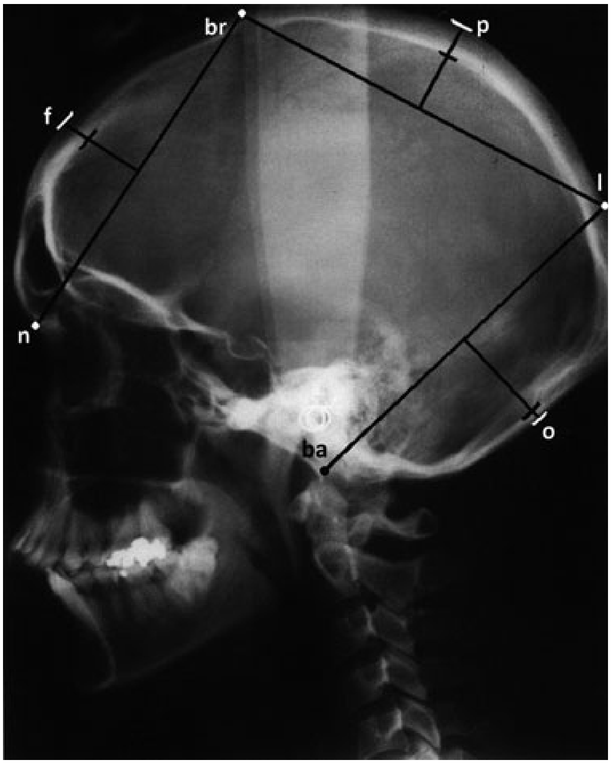

Fig. 1. Profile radiograph of an adult female with skeletal Class II malocclusion. On the radiograph, the location of the cephalometric reference points and lines are marked: Basion (ba): the most posterio-inferior point on the clivus. Bregma (br): the intersection between the sagittal and coronal sutures on the surface of the cranial vault. Frontale (f): the point on the surface of the frontal bone determined by a perpendicular to the nasion-bregma line and passing through its midpoint. Lambda (l): the intersection between the lambdoid and sagittal sutures on the surfaces of the cranial vault. Nasion (n): the most anterior point on the fronto-nasal suture. Reference points according to Björk (40). The thickness of the frontal (f), parietal (p) and occipital (o) bones were defined as the distances from the points where the perpendicular bisectors of the cords nasion-bregma, bregma-lambda and lambda-basion intersected the inner and outer contours of the respective bones. This definition is according to Axelsson et al. (4).

The method errors ranged from 0.3 to 0.6 mm (41) and the reliability coefficients from 0.79 to 0.97 (42).

Statistical methods

The normality of distribution was assessed by the parameters of skewness and kurtosis and by the Shapiro–Wilks w-test. The thickness of the frontal, parietal and occipital bones was normally distributed except for the occipital bone in Class III. Differences in the means of thickness of the frontal, parietal and occipital bones between the malocclusion groups and the control group, and between genders were assessed by unpaired t-tests. The results of the test were considered to be significant at p-values below 0.05. The statistical analyses were performed using SPSS 13.00 (SPSS Inc., Chicago, IL, USA).

Results

Gender differences

Gender differences in the thickness of the frontal, parietal and occipital bones in occlusion groups I and III are presented in Table 2. In Class I, no significant difference in the thickness of the frontal, parietal or occipital bone was found between the females and males. In Class III, no significant difference in skull thickness was found when females and males were compared.

Class II group compared with Class I

Statistically significant differences were found in females in the frontal bone ($p = 0.05$) and in the occipital bone ($p = 0.008$) (Table 3). The frontal bone was thicker and the occipital bone was thinner in the skeletal Class II malocclusion group compared with the female controls.

Class III compared with Class I

The skull thickness in this malocclusion group was comparable to the control group (Table 4).

Discussion

The most important outcome of this study was the finding of a reduced skull thickness in the occipital area and a thickening of the frontal bone in females with skeletal Class II malocclusion compared with females with Class I. It shows that different deviations in the theca cranii are associated with skeletal Class II malocclusions. Therefore, the hypothesis is confirmed for Class II, while the skull thickness in Class III did not deviate from the normal.

This study thus contributes to the aetiological discussion of local variations in skull thickness in healthy adults. In this discussion distinction between a *general* and a *local* alteration in thickness is usually not made. It can be hypothesized that the aetiology behind general and local deviation in skull thickness is different. The finding of a local thickening in the frontal bone might be interrelated with the finding of a short nasal bone in this malocclusion group (35). Both areas belong to the frontonasal developmental field (43). When compared with the skeletal Class III malocclusion it is interesting that Class III subjects have a normal nasal bone length and a normal thickness of the frontal bone.

Differences between skeletal Class II and Class III malocclusion were also found in the cervical spine

Table 2. **Differences in theca thickness between females and males in the control group and the Class III group**

		Females			Males			
Variables	Group	*n*	Mean	SD	*n*	Mean	SD	*p*-value
Frontal	Control	19	7.05	1.24	20	7.28	1.33	NS
	Class III	29	7.11	1.65	24	7.13	1.23	NS
Parietal	Control	19	8.07	1.35	20	8.70	1.11	NS
	Class III	25	7.85	1.39	19	8.22	1.08	NS
Occipital	Control	19	6.19	1.69	20	6.91	1.40	NS
	Class III	25	5.95	2.09	19	6.20	1.86	NS

NS, not significant

Table 3. **Differences in theca thickness between females in the Class II group and females in the control group**

	Class II			Control group			
Variables	*n*	Mean	SD	*n*	Mean	SD	*p*-value
Frontal	25	7.85	1.43	19	7.05	1.24	*
Parietal	23	8.33	1.50	19	8.07	1.35	NS
Occipital	23	4.94	1.13	19	6.19	1.69	**

*p < 0.05; **p < 0.01; NS, not significant

Table 4. **Differences in theca thickness between the Class III group and the control group**

	Class III			Control group			
Variables	*n*	Mean	SD	*n*	Mean	SD	*p*-value
Frontal	53	7.12	1.46	39	7.17	1.27	NS
Parietal	44	8.01	1.27	39	8.39	1.26	NS
Occipital	44	6.06	1.97	39	6.55	1.57	NS

NS, not significant

where the vertebral fusions in Class II were localized more cranially than the fusions in skeletal Class III (31, 33). These differences might be interrelated with the differences in the occipital bone registered in the present study. One explanation of this interrelation could be similarities in the developmental origin from cartilage. The spine has developed cartilaginously, and so has the inferior part of the occipital squama, where the occipital bone thickness is measured. Other explanations of this local thinning of the occipital bone in Class II could be found in the attachment of the neck musculature to this occipital region, which secondarily might influence the head posture.

As a former study on skull thickness in subjects with skeletal deep bite documented a thickening of all three skull bones in subjects with deep bite compared with Class I (29), it seems relevant to revisit our views upon normality. It is suggested that normal standards for skull thickness are subdivided according to occlusion and that normal values for each malocclusion group are added. Also differentiation between retrognathia and prognathia of the maxilla and the mandible in the different malocclusion groups is needed.

The present study presents for the first time data for skull thickness in adults with skeletal Class II and skeletal Class III malocclusion. Similar data for the remaining skeletal malocclusions and for children with skeletal malocclusion are still lacking and needed for future diagnostics of normal and pathological skulls.

Conclusion

The most important outcome of this study was the finding of a reduced skull thickness in the occipital area and a thickening of the frontal bone in females with skeletal Class II malocclusion compared with Class I. The skull thickness in the skeletal Class III malocclusion group did not deviate from Class I. It shows that differences in skull thickness are associated with skeletal malocclusions.

Clinical relevance

Recent studies on profile radiographs have shown that the spine as well as the sella turcica reveal morphological deviations, which are characteristic of different skeletal malocclusions. The present study on differences in skull thickness in Class II and III skeletal malocclusions adds new morphological insight into the phenotypic characteristics of skeletal malocclusions, important for early diagnostics and treatment planning.

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