Skeletal and dental deviation in the sagittal- and vertical plane; a comparison of two diagnostic methods

UNIVERSITETET
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MASTER THESIS
Stud. odont.

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April 2024
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Contents

Acknowledgements

We would like to start by thanking our supervisor, Maud Els-Marie Andersson, Associate Professor at the Department of Orthodontics, University of Oslo, for her excellent guidance throughout our master's thesis and for being so available to us. Thank you for your valuable input and for generously sharing your knowledge. We also want to thank Gerald Torgersen, Lecturer at the Department of Maxillofacial Radiology at University of Oslo, for his technical expertise and assistance in transferring scanned images to FACAD®. Additionally, we would like to extend our gratitude to our future dental colleague, Pinar Salih, for laying the groundwork for this master's thesis.

Salih examined nearly 600 plaster models from 155 individuals in her work, investigating the correlation between dentoalveolar Angle Class II and disto-basal jaw relation in the sagittal plane. The sample was extirpated from the Nittedal Study (conducted in the 1970s and 1980s) with Professor Olav Slagsvold as the leading initiator.

Our work is an extension of Salih's work in that, in addition to the Angle Class II sample in the sagittal plane, we have also examined Angle Class I samples and the Angle Class II samples in both the sagittal and vertical planes.

Only a few comparable archives exist around the world, and since such data is under-researched, we wanted to take the opportunity to examine the archive's data and present our findings in this master's thesis.

Abstract

Aim: The aim of the study was to describe the relationship between the sagittal and vertical skeletal relations with the dentoalveolar Angle I and Angle II classes.

Materials: The study was systematically reviewed by the authors to include a sample of 138 children born between 1967 and 1972, with normal occlusion.

Method: The various collected data were retrieved from the Oslo Craniofacial Growth Archives (OCGA) at the Department of Orthodontics, University of Oslo. The sample was extirpated from the Nittedal Study, conducted in the 1970s and 1980s. The sample was further divided into three subgroups: Angle Class I, II, and III molar relation, as diagnosed on the archived plaster models. Furthermore, individuals with Angle Class I and Angle Class II molar relations were further analysed in relation to the skeletal jaw relation in both the sagittal and vertical planes.

Results: Out of the 77 children with Angle Class I molar relation, 39.0% had relative prognathism, 40.3% had relative retrognathism, and 20.8% had relative orthognatism. Out of the 61 children with Angle Class II molar relation, 72.1% had relative prognathism, 11.5% had relative retrognathism, whilst 20.8% had relative orthognatism.
Out of the 77 with Angle Class I molar relation, 81.8% had normal vertical basal relation, 6.5% were hyperdivergent, and 11.7% were hypodivergent. Out of the 61 with Angle Class II molar relation, 75.4% had normal vertical basal relation, 1.6% were hyperdivergent, and 23.0% were hypodivergent.

Conclusion: For those with Angle Class I, there seems to be a fairly even distribution among the various skeletal jaw relations compared to the Angle Class II sample, where most present with a relative maxillary prognathism. However, in the vertical plane the majority of the objects with Angle Class I as well as Angle Class II seems to have a normal basal jaw relation.

Keywords: sagittal plane, vertical plane, skeletal classification, angle molar relationship, lateral cephalogram, cephalometric analysis, orthodontic treatment, orthognathic, prognathic, retrognathic, hyperdivergent, hypodivergent, occlusion development

Introduction

Skeletal and dental occlusion

As known, malocclusion can occur through dental-, dentoalveolar- or skeletal discrepancy. There are several different classification systems that describe the different malocclusions. The correlation between craniofacial morphology and dental occlusal relationships has attracted significant attention (1). Occlusion is assessed by considering the sagittal, vertical, and transversal alignments of maxillary and mandibular dental arches, displacement of teeth, crowding, spacing, agenesis and supernumerary teeth (2).

In 1899, Edward Hartley Angle, regarded as the father of modern orthodontics, introduced a malocclusion based on the sagittal relationship of the dental arches. He focused on the first molars and the canines in both jaws because of their stability regarding the position in the jaw and is used as an expression of the antero-posterior relation between the jaw's skeletal parts (3).

Angle's classification and Sagittal relationships

Edward Angle created three different classes regarding the sagittal relationship of the dental arches: Angle Class I, Angle Class II - division I and II, and Angle Class III (*Figure 1)*.

The definition of normal occlusion is something Angle described as the following: *"The upper first molars are the key to occlusion and the upper and lower first molars should be related so that the mesiobuccal cusp of the upper molar occludes in the buccal groove of the lower molar. If the teeth are arranged on a smoothly curving line of occlusion and this molar relationship exists, then normal occlusion would result."* (4).

1) Angle Class I – Angle defined that as the definition above, but deviations can still appear if the position of the other teeth in the maxillary or mandibular arch is deviant. Example: Rotations, tipping, retention, lack of space, agenesis.

Malocclusion is the opposite of normal occlusion and is defined as:

"The nature of malocclusion, not a disease but rather a variation from accepted societal norms that can lead to functional difficulties or concerns about dentofacial appearance for a patient" (5).

2) Angle Class II – a distal relation of the lower arch when related to the upper arch, the lower arch first permanent molar locking more than one-half of a cusp distal to normal relation with the upper first permanent molar. This class is divided into Division I, those cases exhibiting protruding upper incisors; and Division II, those cases exhibiting retruded upper incisors (6).

3) Angle Class III - a mesial relation of the lower arch when related to the upper arch, the lower first permanent molar locking more than one-half cusp mesial to normal relation with the upper first permanent molar (10).

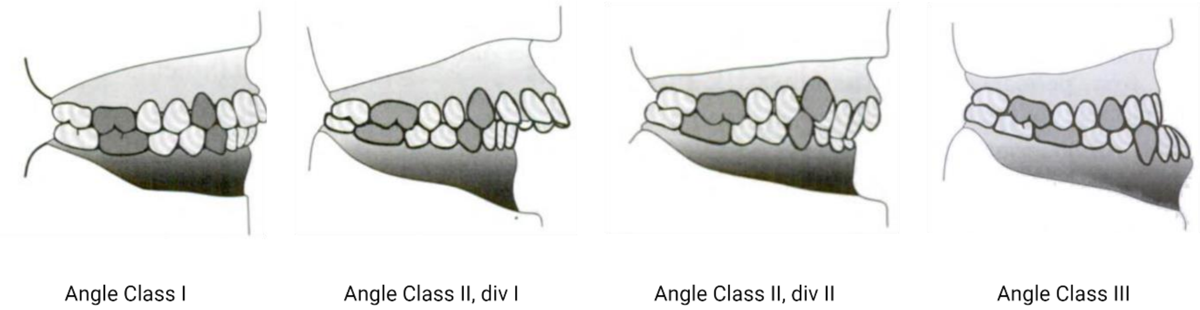

Figure 1: Angle Classification based on the first molar and canine relationship. Class I (neutral occlusion), Class II (disto-occlusion) and Class III (mesio-occlusion). Adapted from (7) on biorender.com.

The classification of the incisors can also be categorised as Class I, II and III depending on the positioning of the lower incisors in relation to the cingulum plateau of the upper central incisors.

The upper canine's cusp may occlude in the space between the first premolar and the canine in the lower jaw as shown in the first image in *Figure 1*. This occurrence is known as a Class I canine relationship. Class II and III canine relationships also occur. When there is a class II relationship the lower canine is placed distally for the upper canine, and the upper canine appears between the lower canine and the lower lateral incisor. At Class III relationship the lower canine is placed more mesial for the upper canine. The upper canine appears between first and second premolar (8).

To achieve a perfect Angle Class I molar relationship, it requires accurate tooth size as well as accurate dental arch proportioning (4).
Angle Class II molar relationship is relatively prevalent (14-18%) and is more common in Northern European populations compared to Angle Class III molar relationship. The prevalence of the latter has been found to be approximately 3-4% (9).

The Selmer-Olsen system

Another orthodontist by the name Selmer-Olsen had a different classification of malocclusion compared to Edward Angle. He relied on the relationship between the opposing dental arches based on the antero-posterior and vertical relationships in the front, as well as the transversal relationships in the lateral segments (7).
Selmer-Olsen distinguished between five main types of malocclusions: Overjet, underbite, open bite, deep bite, crossbite and scissor bite, which were further distinguished into two groups based on the origin of the craniofacial discrepancy: dento-alveolar deviation and skeletal deviation.
His classification system gave a comprehensive comparison between the relationship of the front teeth of the two jaws, in both the horizontal- and vertical planes, as well as the transversal relationships in the lateral segments (3).

Vertical relationship and Anterior Open bite

Anterior open bite is defined as the absence of contact between incisors in the maxilla and mandible (10, 11).
Generally, it results in worsening of facial features, reduces the ability to chew optimally and communicate effectively, hence creating uncomfortable situations for the individual (12).
The prevalence of open bite malocclusion in the mixed dentition is high, approximately 17%.
The potential outcome for correcting this malocclusion varies from favourable to unsatisfactory, depending on the severity of the condition and the age of the patient (13).

Aetiology of occlusion

The aetiology of both normal occlusion and malocclusion is something that is of great concern for orthodontists, both in terms of orthodontic treatment planning and research. There is now much research that supports the idea that the aetiology behind occlusion is multifactorial, concerning both the genetics of the individual in addition to multiple potential causative environmental factors (14-16).

Studies have shown that there are familiar similarities when it comes to the development of the craniofacial complex, both in terms of basal skeletal patterns as well as growth and development of the maxilla and the mandibula, all of which is of great importance when it comes to the establishment of occlusion. A great example of this is the “Habsburg jaw”, a characteristic facial phenotype presenting with a marked retrognathic maxilla, consequently giving these patients a seemingly protrusive chin. Historically this was a typical orthodontic and dental family trait found in the Habsburg family dynasty in Austria (17).

Environmental factors that are responsible in the process and establishment of dental occlusion involve the growth and development of facial soft tissue, most importantly the tongue, the chin, muscles of mastication, lips, and adenoids.
Yet another relevant factor in occlusion which also is of great concern for orthodontists, are conscious and unconscious parafunctional activities like mouth-breathing, thumb sucking, and tongue thrust, all of which are known to cause malocclusions like crossbite and anterior open bite (18).

Environmental factors

Anterior open bite can be regarded as a functional outcome resulting from various functional etiologic factors. Among these factors, the most significant ones include deleterious oral habits, oral breathing, as well as other environmental causes such as traumatic events and pathologies (19-27).

Deleterious habits

In a normal occlusion, there is a balanced relationship among the oral structures. The teeth are positioned in a balanced manner receiving opposing forces internally by the tongue and externally by the lips and cheeks (28).

Some abnormal function of the oral muscles by deleterious habits has a negative impact on the teeth and the occlusion. Examples of deleterious habits like non-nutritive sucking behaviours, such as pacifier and thumb-sucking, along with atypical tongue thrust and anterior tongue positioning, have the potential to disrupt the muscular balance (29).

Pacifier and thumb-sucking

Humans commence the act of sucking their fingers, tongue, and lips during the prenatal stage in the maternal womb. When humans are born, they are born with a well-developed function of sucking to acquire the essential nutrients for survival. It is through breastfeeding and the subsequent development of children not only obtain the essential nutrients necessary to fulfil their physiological needs, but also to experience sentiments of security, warmth, and acceptance, which are imperative for their overall well-being and their proper emotional maturation (30).

Continued presence of pacifier or thumb-sucking until the mixed dentition is considered as an abnormality, as these habits have a strong causative effect on malocclusion, especially in relation to the development of an anterior open bite (31, 32).

The use of a pacifier, or the act of thumb-sucking can function as mechanical obstacles and prevent the front teeth from erupting further and create an open bite (33).

The occurrence of an open bite is not developed in every child, but it depends on various factors such as the manner in which the habit is exercised, it depends on the duration the child maintains the pacifier in position, the frequency of pacifier usage throughout the day, and on the intensity which means degree of force exerted by the habit (34).

Anterior tongue posture and tongue thrust

Atypical positioning of the tongue and an atypical tongue thrust can be observed in all the cases of anterior open bite (35).

The tongue has a secondary role in the aetiology of anterior open bite, as it can maintain and exacerbate the existing open bite when it is positioned between the teeth. The positioning can occur at rest, speech, and swallowing. Of these, the tongue posture at rest has the greatest deleterious risk, as it remains between the teeth for a significant duration of time (36).

In presence of open bite, the maturation of the masticatory apparatus occurs differently, leading to a deviation from the normal swallowing pattern to an atypical swallowing pattern or tongue thrust swallow. This atypical tongue thrust may result in absence from masseter contraction and activity of perioral muscles. Consequently, tongue thrust during swallowing is considered to be a secondary factor in the aetiology of open bite (33).

Mouth breathing

In the presence of nasal obstruction, there can be an impairment or blockage in the airflow, causing the child to start breathing through the mouth. Nasal obstruction is divided into upper and lower respiratory obstacles. The upper obstacles encompass conditions such as hypertrophied adenoids, allergic rhinitis, hypertrophied nasal turbinate, and deviation of nasal septum. On the other hand, the lower obstacles involve hypertrophied tonsils or frequent tonsillitis (24).

In the primary dentition, the prevalence of anterior open bite in children with mouth breathing is 30%, which is strictly comparable to the general population. However, in the mixed- and permanent dentition remains almost the same but decreases in the overall population (12- 20%) (37).

Upper respiratory obstacles

Hypertrophied adenoids

Adenoid hypertrophy refers to the abnormal enlargement of the adenoids, which might lead to a complete obstruction of the upper airways. In some cases, excessive growth of the adenoids can result in a partial blockage, causing significant discomfort for the patient as they attempt to breathe through their nose. Consequently, these patients may resort to mouth breathing to compensate for the lack of optimal breathing through their nose (38).

The abnormal growth of adenoids can contribute to sleep-disordered breathing in paediatric patients. It has been observed that children with increased sleep-disordered breathing and obstructive sleep apnea symptoms tend to exhibit common characteristics in the vertical plane, such as long face, retro-positioned mandibles, and lip incompetence (39, 40). Additionally, there has been observed some characteristics in the transverse plane, such as maxillary constriction, which usually occurs simultaneously with reduced transverse dimension of the upper airways. This, in turn, leads to an increase in nasal resistance and subsequently encourages mouth breathing.

Nasal septum deviation

The nasal septum is the anatomical structure that separates the two airways and nostrils. A deviated septum of the nose refers to a displacement from the central or midline position. The deviation of the nasal septum is considered an abnormality whereby a portion of the cartilaginous tissue deviates towards one side of the nostril, causing an obstruction for the airway passage on the side it is deviated to. While many individuals may have a deviated nasal septum without experiencing any symptoms, there are cases where the deviation is severe enough to impede the flow of the air through the nostrils, which may affect negatively and lead to potentially complications for the patient (41).

The two main causes of this condition are impact trauma, such as blow to the face, and a congenital disorder resulting from compression of the nose during childbirth (41). Common symptoms associated with nasal septum deviation include sinusitis, sleep apnea, snoring, repetitive sneezing, facial pain, nosebleeds, and difficulty breathing.

In children, chronic nasal breathing obstruction caused by nasal septum deviations is often accompanied by an increase in upper anterior facial height in comparison to individuals who can breathe through their nose. Additionally, mouth-breathing patients with deviation of nasal septum tend to exhibit a retrognathic maxilla and mandible in terms of the anteroposterior position of the jaws.

Mouth-breathing patients due to nasal septum deviations often present with Class II malocclusion, in contrast to nose-breathing subjects who typically have normal occlusion (42).

When looking at these patients it has been registered that a correlation between nasal resistance and open bite is 8.2% when assessing children between the ages of 7 and 15 (43).

Lower respiratory obstacle

Hypertrophied palatine tonsils

The tonsils are a pair of structures that are part of the lymphatic system. They are located at the entrance to the upper airway and are primarily to assist the body in defending against respiratory infections and preventing the entry of organisms through the mucosal respiratory system. These tonsils are part of a larger structure called Waldeyer’s ring, which includes the nasopharyngeal tonsil or adenoid (NT), the paired tubal tonsils (TT), the paired palatine tonsils (PT) and the lingual tonsils (LT) (44).

Tonsillar hypertrophy refers to the enlargement of the tonsils without presence of inflammation, and it can manifest in various sign and symptoms, such as sleep disturbance, loud snoring, irregular breathing, coughing, night choking, interrupted sleep apnea, dysphagia, and excessive daytime sleepiness (44).

In children with mouth breathing, because of hypertrophied palatine tonsils, the position of the mandible is lowered most of the time to keep the mouth open, which also affects the tongue's position and will make the tongue follow the mandible. This may result in lack of contact between the tongue and the palate during rest (33), leading to lingual forces exerted by the buccinator muscle and causing a smaller transverse development of the upper jaw and causing posterior crossbite. Concurrently, this will make a greater posterior vertical development of the palate. Additionally, the tongue resting on the anterior teeth can restrict their vertical development and contribute to an anterior open bite.
Mouth breathing is a common cause of both posterior crossbite and anterior open bite.
The association between mouth breathing and anterior open bite has a prevalence of 35.5% in children ages between 3 and 6 years (45).

Traumatisms

Dental traumas have the potential to induce ankylosis, because of an injury which causes changes in the PDL, and forms a bone bridge linking the cementum and lamina dura. The occurrence of ankylosis in the primary tooth may not only lead to its retention but also promote a delay or even lead to an ectopic eruption of the permanent successor and make the tooth in a position of infraocclusion, and thereby causing an open-bite malocclusion (46).

Genetic Factors

Growth pattern

When it comes to growth patterns, patients can be classified into three distinct groups based on their growth pattern: horizontal-, normal- and vertical growth pattern.
Out of these three groups more individuals with vertical growth patterns develop open bite compared to those with a balanced or horizontal growth pattern (47, 48).

The horizontal growth pattern typically exhibits a low mandibular plane and gonial angles, reduced lower anterior face height, deep overbite, increased free-way space, decreased molar and incisor dentoalveolar heights, and greater biting force compared to individuals with a vertical growth pattern (47-52).

Individuals with vertical growth patterns are more susceptible to environmental factors that predispose them to open bite malocclusion (48, 51, 53). It is important to note that not all individuals with a vertical growth pattern do not develop open bite because of the compensatory eruption mechanism (51, 54), but the incidence of open bite is still higher in this group than the other groups.

Pathologies

Craniofacial anomalies

Certain congenital deformities and syndromes have the potential to cause malocclusion, especially including the occurrence of anterior open bite.

Cleidocranial dysostosis, which is a congenital deformity often linked to hereditary factors and may be associated with the presence of anterior open bite (55).

Treacher Collins syndrome involves hypoplastic mandible, glossoptosis, small size of the pharynx and nasopharynx, and occasionally choanal atresia, which can lead to severe breathing difficulties, and consequently, open bite malocclusion (56).

Excessive tongue activity during swallowing or even at rest can change the axial inclinations of the incisors and result in an open bite. This phenomenon is frequently observed in patients with some form of neurological impairment (57).

Juvenile rheumatoid arthritis is a condition that affects the oral cavity and is characterised by the presence of anterior open bite, restricted mouth opening, and in most cases, compromised TMJ (58, 59).

Cephalometrics

Cephalometric radiography is a crucial instrument for the identification and diagnosis of dental malocclusions and skeletal discrepancies. Its inception has led to the utilisation of cephalometric radiography for two primary objectives. Firstly, it has facilitated research on the correlation between the morphology of various tissues that comprise the facial skeleton. Secondly, it has contributed significantly to clinical practice, including diagnosis, treatment planning, and reassessment of treatment-induced alterations (14, 60-62).

Cephalometrics is one of the primary tools that is applied during preoperative orthodontic treatment. For most part it is routinely used for the treatment planning of standard orthodontic treatments, but indeed also for more elaborate treatment planning preoperatively before orthognathic surgery (63).
A cephalogram is in simple terms a lateral x-ray image of the cranial vault encompassing the encephalon and shows an overview of the maxillary and mandibular positioning in regard to an arrangement of basal skeletal structures (63).

A cephalometric analysis is a clinical application that uses different anatomical landmarks displayed on a cephalogram to visualise the positioning of the maxilla and mandible in relation to these selected landmarks. Two widely used methods of cephalometric analysis are the Steiner analysis and the McNamara analysis (64).
Both methods involve the manual tracing by an operator using a cephalometric tracing program like FACAD®. Modern tracing techniques have an objective to transcend the intraindividual operator discrepancies that may lead to operator tracing errors. There is now much research on the use of artificial intelligence (AI) and machine deep learning to give a more valid and reproducible tracing results (65).

In regard to cephalometric analysis, a handful of important anatomical structures are used for the tracing process, as seen in *Figure 2*.
In the determination of the maxilla and mandible relation to the craniofacial vault in the sagittal plane, four cephalometric landmarks are used routinely: *S-point (sella turcica ossis sphenoidalis), N-point (nasion), A-point (*deepest concavity on the anterior maxilla) and *B-point* (deepest concavity on the mandibular symphysis) (66).

When comparing the maxilla and mandible positioning to the craniofacial vault in the vertical dimension, six different cephalometric landmarks are routinely used: *S-point (sella turcica ossis sphenoidalis), N-point (nasion), PNS (spina nasalis posterior), ANS (spina nasalis anterior), Gn (gnathion* – the most anterior inferior point of the mandibular symphysis*), Go (gonion* – the most posterior inferior point of the mandibular angle*) (66).*

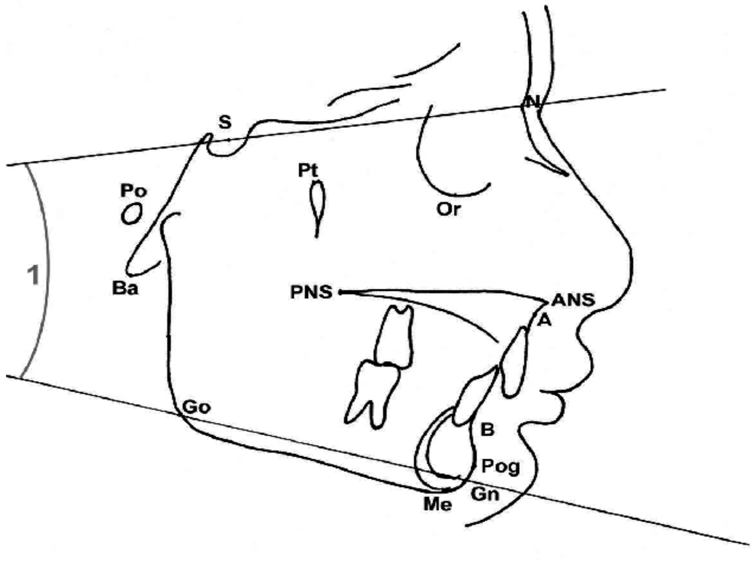

Figure 2: The different anatomical skeletal landmarks used for cephalometric analysis in both the sagittal and vertical planes (67).

Method

Background

This current study utilises retrospective data from 138 individuals with normal occlusion, who were born between 1967 and 1972. These individuals were chosen by chance from the Oslo Craniofacial Growth Archives (OCGA), which is collection of dental arch plaster models, lateral cephalograms, and orthopantomograms obtained from over 2000 healthy individuals who were regularly assessed every three years from the age of 6 to 21. The archives were compiled in the 1970s and 1980s from the Nittedal community outside Oslo (68).

The initial group of 138 children was further divided into three categories based on Angle's first molar classification system, as determined from the different plaster models.
77 children were categorised as having Angle's Class I molar relationship, while 61 children were identified as having Angle's Class II molar relationship, and only 4 children were classified with Angle's Class III molar relationship. The latter was not included in the study.

None of the children exhibited significant crowding or spacing issues, no open bite, deep bite with either buccal and/or palatal overbite, no agenesis of any permanent teeth except wisdom teeth, and furthermore none of the children received any orthodontic treatment prior to or during the observation period (69).

The samples of participants which were analysed consisted in a total of 138 children, where 61 children met the criteria for Angle's Class II molar relationship and the remaining 77 children were categorised with Angle's Class I molar relationship. The age of the children in both sample groups at the time of data collection was 12 years.
These individuals were further examined in terms of their craniofacial morphology using cephalometric analysis.

Cephalometric Analysis

To evaluate the morphological characteristics, the lateral cephalometric radiographs were applied on the children obtained during the collection of the OCGA. The analogue radiographs were scanned and digitised using an Epson Perfection V750 PRO® (Seiko Epson Corporation, Japan) flatbed scanner connected to a computer, with a resolution of 300 DPI.

The digital tracing software utilised for cephalometric analysis was FACAD® (Illexis AB, Linköping, Sweden). The imported radiographs in FACAD® were then adjusted according to actual size through a magnification adjustment of 5.6%. Subsequently, four cephalometric landmarks were applied for the sagittal craniofacial relation, and six cephalometric landmarks were used for the vertical craniofacial relation. These landmarks were individually identified digitally utilising the analysing-toolbar in FACAD®.

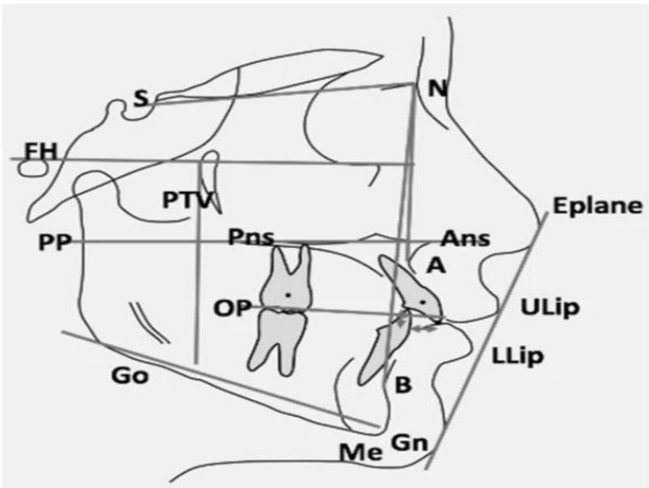

Figure 3: Overview of the cephalometric landmarks and the different tracing lines used for the vertical and sagittal cephalometric analysis (70).

Cephalometric tracing lines

For the sagittal relation two different tracing lines were used to determine the maxilla and mandibular relation to the cranial vault. *SNA* indicates a drawn line from the S-point to the N-point and to the A-point. *SNB* indicates a drawn line from the S-point to the N-point to the B-point. *ANB* describes the relative angle of maxillary prognathism and is the angle difference between *SNA* and *SNB.*

In regard to the vertical relation three different tracing lines were used during the tracing process. The *ML/NSL* line describes the mandibular line (drawn from *Gonion* to *Gnathion*) in relation to the *nasion-sella-line*.
The NL/NSL tracing line describes the relation between the *nasal line* and *nasion-sella-line*. Furthermore, the *ML/NL* line indicates the relative angular relationship between the *mandibular line* and the *nasion line*.

Name	Description	Norm	Standard deviation	Unit
SNA	The angle around the centre N and between the markers A and S	82	3	°
SNB	The angle around the centre N and between the markers B and S	79	3	°
ANB	The angle around the centre N and between the markers A and B	2-3		°
ML/NSL	The angle between the line NSL and the line ML	33	4	°
NL/NSL	The angle between the line NSL and the line NL	7	3	°
ML/NL	The angle between the line NL and the line ML	23.5	5	°

Table 1: Overview of the different cephalometric reference lines and values. The reference values are given for each reference line. A relative maxillary prognathism is described with an ANB > 4 degrees, a relative maxillary retrognathism with ANB < 1 degrees and maxillary orthognatism with ANB 2-3 degrees. Values and reference lines taken from FACAD®.

Reliability

Before the actual tracing process, the authors used a handful of different cephalograms to compare these initial tracings records with that of our supervisor as well as Salih's tracings. This was done with the intention of calibrating our tracings, thereby increasing the validity and reproducibility of our results.

To optimise the tracing records the authors conducted a calibration for defining the landmarks and performed one registration each of four landmarks for sagittal determination and six landmarks for vertical determination. To minimise variation and degree of operator errors, the registrations of the sagittal and vertical tracings were averaged together to give the final values. Each cephalometric x-ray was individually analysed and compared to the plaster model of each patient specimen. The measurements obtained through digital tracing were rounded to nearest 0.1°.

Results

Sagittal basal relation (%)	Class I	Class II
Prognathic	39.0%	72.1%
Retrognathic	40.3%	11.5%
Orthognathic	20.8%	16.4%

Table 2: Overview of the different sagittal basal relations in both the Angle class I and Angle class II subject’s specimens.

Vertical basal relation (%)	Class I	Class II
Hyperdivergent	6.5%	1.6%
Hypodivergent	11.7%	23.0%
Normal	81.8%	75.4%

Table 3: Overview of the different vertical basal relations in both the Angle class I and Angle class II subject’s specimens.

Discussion

Findings

In our study 77 patients were classified with having Angle class I molar relationship, whilst 61 patients had Angle class II molar relationship. Regarding the sagittal dimension, of the 61 Angle class I children 39.0 % had a relative prognathism, 40.3% had a relative retrognathism whilst 20.8 % had a relative orthognatism.

For class II molar relationship 72.1% of the subjects had a relative maxillary prognathism, 11.5% had a relative maxillary retrognathism whilst 16.4% had a relative maxillary orthognatism.

Interestingly only 20.8% of those with an Angle Class I molar relationship had a skeletal Class I or a relative maxillary orthognatism. As many as 72.1% of the children with molar Angle Class II had a skeletal Class II relationship, or a relative maxillary prognathism. There seems to be that even with a basal deviation from the ideal, these children undergo a form of dentoalveolar compensation that enables the establishment of a neutral, Angle Class I occlusion.

Regarding the vertical basal relation, the majority of the subjects, more specifically 81.8% of the Angle Class I subjects and 75.4% of the Angle Class II subjects have a normal vertical basal relation. There seems to be more subjects with an Angle Class II molar pattern that are skeletal hypodivergent (23.0%) in comparison to the Angle Class I subjects (11.7%).
Only a small percentage of the subjects falls into the category of a hyperdivergent vertical basal relation, with only 6.5% of the Class I subjects and 1.6% of the Class II subjects to do so.

Limitations of the study

One of the main limitations of our study was the subjects in each Angle class. Statistically we would have liked to have additional subjects in each of the two categories, as this would have given a greater statistical strength of our results.

Furthermore, on some of the tracings there were some inter individual discrepancies in terms of tracing values, which may have interfered with the final results.

Conclusion

In conclusion, this comprehensive exploration into skeletal and dental occlusion sheds light on the intricate relationship between craniofacial morphology and occlusal relationships. The classification systems pioneered by Edward Angle and Selmer-Olsen have provided valuable frameworks for understanding malocclusions, particularly in terms of sagittal, vertical, and transversal alignments of dental arches.

Angle's classification system, focusing on sagittal relationships, delineates three main classes of malocclusion. Class I represents a neutral occlusion, while Class II and Class III denote disto- and mesio-occlusions, respectively. Selmer-Olsen's system further expands the classification to include various types of malocclusions based on antero-posterior, vertical, and transversal relationships, highlighting the multifaceted nature of occlusal discrepancies.

The aetiology of malocclusion is multifactorial, encompassing genetic predispositions and environmental influences such as deleterious oral habits, mouth breathing, and traumatic events. Genetic factors play a significant role, with vertical growth patterns being linked to an increased susceptibility to certain types of malocclusions, including open bite. Additionally, craniofacial anomalies and pathologies can contribute to the development of malocclusions, underscoring the complex interplay of genetic and environmental factors.

Cephalometric analysis serves as a valuable tool for diagnosing and evaluating malocclusions, providing insights into craniofacial morphology and facilitating treatment planning. However, this study acknowledges certain limitations, including sample size constraints and potential inter-individual tracing discrepancies, which may impact the robustness of the findings.

For those with Angle Class I, there appears to be a fairly even distribution among the various skeletal jaw relations compared to the sample with Angle Class II, where most of the individuals present with a relative maxillary prognathism.

In the vertical plane, the vast majority in the sample have a normal basal jaw relation, this applies to those with Angle Class I and Angle Class II.

Overall, this study contributes to our understanding of skeletal and dental occlusion, emphasising the importance of considering various factors in the assessment and management of malocclusions. Further research addressing these complexities is warranted to enhance treatment outcomes and improve patient care in orthodontics.

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Appendix

Id	Nit. id	Dental relation (Angle Class) I	Dental relation (Angle Class) II	Tracing JB SNA	Tracing JB SNB	Tracing JB ANB	Tracing TC SNA	Tracing TC SNB	Tracing TC ANB	MEAN AVERAGE SNA	MEAN AVERAGE SNB	MEAN AVERAGE ANB	Skeletal relation sagittal plane R	Skeletal relation sagittal plane O	Skeletal relation sagittal plane P	Tracing JB ML/NSL	Tracing JB NL/NSL	Tracing JB ML/NL	Tracing TC ML/NSL	Tracing TC NL/NSL	Tracing TC ML/NL	MEAN AVERAGE ML/NSL	MEAN AVERAGE NL/NSL	MEAN AVERAGE ML/NL	Skeletal relation vertical plane Hyper-divergent	Skeletal relation vertical plane Hypo-divergent	Skeletal relation vertical plane Normal
1	N1465	x		76.7	74.7	2.0	77.5	74.5	2.9	77.1	74.6	2.5		x		34.6	7.4	27.2	34.3	9.4	24.9	34.5	8.4	26.1			x
2	N1470		x	85.3	79.7	5.6	79.1	75.0	4.1	82.2	77.4	4.9			x	34.2	9.8	24.3	41.1	18.0	23.1	37.7	13.9	23.7			x
3	N1471	x		83.6	79.0	4.6	81.9	78.8	3.0	82.8	78.9	3.8			x	31.3	4.5	26.8	38.0	5.9	32.2	34.7	5.2	29.5	x		
4	N1475	x		89.6	82.6	7.0	88.5	81.8	6.7	89.1	82.2	6.9			x	22.0	4.6	17.3	23.2	4.3	18.9	22.6	4.5	18.1		x	
5	N1481	x		84.2	78.0	6.2	87.1	79.2	8.0	85.7	78.6	7.1			x	25.8	7.3	18.5	27.1	12.1	15.0	26.5	9.7	16.8		x	
6	N1482		x	80.4	77.3	3.1	80.3	78.0	2.3	80.4	77.7	2.7		x		35.9	6.2	29.6	36.5	7.0	29.5	36.2	6.6	29.6	x		
7	N1484		x	84.9	78.3	6.6	86.2	79.5	6.7	85.6	78.9	6.7			x	28.5	8.1	20.5	30.5	1.5	29.0	29.5	4.8	24.8			x
8	N1491		x	89.8	81.1	8.7	85.8	79.2	6.7	87.8	80.2	7.7			x	32.4	14.1	18.3	32.9	6.5	26.4	32.7	10.3	22.4			x
9	N1494	x		83.3	80.3	3.0	81.7	80.3	1.4	82.5	80.3	2.2		x		30.9	6.1	24.8	29.9	8.3	21.6	30.4	7.2	23.2			x
10	N1502	x		80.1	75.9	4.2	84.2	78.4	5.8	82.2	77.2	5.0			x	34.3	13.4	20.9	32.4	10.5	21.8	33.4	12.0	21.4			x
11	N1506	x		81.2	76.2	4.9	84.3	80.7	3.7	82.8	78.5	4.3			x	30.4	8.2	22.2	30.4	5.6	24.8	30.4	6.9	23.5			x
12	N1507		x	84.1	77.1	7.0	86.9	80.0	6.9	85.5	78.6	7.0			x	25.2	10.5	14.7	25.1	10.4	14.7	25.2	10.5	14.7		x	
13	N1511		x	85.2	80.3	4.9	86.3	81.9	4.4	85.8	81.1	4.7			x	25.8	8.3	17.5	26.0	8.7	17.3	25.9	8.5	17.4		x	
14	N1512	x		83.6	77.7	5.9	85.2	79.4	5.8	84.4	78.6	5.9			x	33.2	10.4	22.8	31.7	9.1	22.5	32.5	9.8	22.7			x
15	N1513	x		82.7	80.8	2.0	80.2	79.6	0.6	81.5	80.2	1.3	x			29.4	8.7	20.7	30.0	7.6	22.4	29.7	8.2	21.6			x
16	N1514	x		77.4	75.3	2.2	75.9	75.9	0.0	76.7	75.6	1.1	x			29.0	6.7	22.2	28.3	9.4	18.9	28.7	8.1	20.6			x
17	N1517	x		82.4	80.4	2.0	80.3	80.3	-0.1	81.4	80.4	1.0	x			30.2	5.0	25.2	30.8	6.4	24.5	30.5	5.7	24.9			x
18	N1521		x	87.0	84.1	2.9	86.2	84.5	1.8	86.6	84.3	2.4		x		23.4	6.3	17.1	24.9	9.9	15.0	24.2	8.1	16.1		x	
19	N1526	x		75.2	73.2	2.0	73.5	72.8	0.7	74.4	73.0	1.4	x			35.3	12.0	23.3	35.2	19.3	15.9	35.3	15.7	19.6			x
20	N1531	x		81.4	79.9	1.5	80.1	79.3	0.3	80.8	79.6	0.9	x			26.5	11.2	15.3	26.9	13.6	13.3	26.7	12.4	14.3		x	
21	N1534	x		83.3	80.4	2.9	80.3	79.1	1.2	81.8	79.8	2.1		x		29.5	6.6	22.9	28.6	8.0	20.6	29.1	7.3	21.8			x
22	N1538		x	87.9	81.6	6.3	84.0	79.3	4.7	86.0	80.5	5.5			x	19.4	2.9	16.5	21.3	9.3	12.1	20.4	6.1	14.3		x	
23	N1540	x		82.2	77.9	4.3	75.9	72.3	3.6	79.1	75.1	4.0			x	35.4	4.9	30.4	42.7	19.7	23.7	39.1	12.3	27.1			x
24	N1542	x		86.8	82.8	4.0	81.1	76.9	4.3	84.0	79.9	4.2			x	29.7	3.8	25.9	34.1	11.2	22.9	31.9	7.5	24.4			x

25	N1543	x		85.4	83.7	1.7	82.0	81.5	0.5	83.7	82.6	1.1	x			31.9	7.3	24.6	32.5	10.1	22.4	32.2	8.7	23.5			x
26	N1544		x	82.9	78.8	4.1	82.5	77.3	5.2	82.7	78.1	4.7			x	28.9	5.9	23.0	29.0	7.9	21.1	29.0	6.9	22.1			x
27	N1548	x		73.6	72.4	1.2	68.2	66.4	1.8	70.9	69.4	1.5	x			37.3	7.6	29.7	46.0	16.3	29.7	41.7	12.0	29.7	x		
28	N1550		x	82.4	74.2	8.2	82.8	75.0	7.7	82.6	74.6	8.0			x	33.2	12.8	20.4	34.4	15.8	18.6	33.8	14.3	19.5			x
29	N1552	x		84.4	76.7	7.7	81.3	74.0	7.2	82.9	75.4	7.5			x	34.9	12.2	22.6	38.8	15.7	23.1	36.9	14.0	22.9			x
30	N1554		x	86.6	82.0	4.6	85.0	81.1	4.0	85.8	81.6	4.3			x	21.4	3.8	17.6	20.8	7.2	13.6	21.1	5.5	15.6		x	
31	N1560	x		82.2	79.9	2.3	80.8	79.2	1.5	81.5	79.6	1.9	x			25.9	12.4	13.5	25.7	12.8	12.9	25.8	12.6	13.2		x	
32	N1656		x	83.6	77.4	6.2	79.4	73.8	5.5	81.5	75.6	5.9			x	24.1	3.4	20.7	25.5	4.7	20.8	24.8	4.1	20.8			x
33	N1668		x	80.3	73.3	6.9	83.9	75.2	8.8	82.1	74.3	7.9			x	34.3	14.6	19.7	33.2	12.4	20.7	33.8	13.5	20.2			x
34	N1674		x	84.4	76.2	8.2	81.7	77.3	4.4	83.1	76.8	6.3			x	31.3	9.9	21.5	30.6	9.7	20.9	31.0	9.8	21.2			x
35	N1675	x		85.0	78.6	6.4	84.9	79.2	5.7	85.0	78.9	6.1			x	29.4	7.6	21.8	29.9	8.7	21.3	29.7	8.2	21.6			x
36	N1678		x	88.8	83.3	5.5	86.5	82.3	4.1	87.7	82.8	4.8			x	26.1	6.7	19.4	27.2	9.4	17.8	26.7	8.1	18.6			x
37	N1679	x		95.3	88.1	7.2	94.0	87.4	6.6	94.7	87.8	6.9			x	25.4	5.9	19.5	26.9	4.2	22.7	26.2	5.1	21.1			x
38	N1681	x		79.5	76.6	2.9	79.4	77.8	1.6	79.5	77.2	2.3		x		34.1	5.8	28.4	35.2	9.4	25.8	34.7	7.6	27.1			x
39	N1682	x		84.1	77.8	6.3	83.6	79.7	4.9	83.9	78.8	5.6			x	34.7	8.2	26.5	33.3	8.5	24.7	34.0	8.4	25.6			x
40	N1683		x	90.3	81.7	8.6	90.2	82.2	8.0	90.3	82.0	8.3			x	26.8	7.1	19.7	27.4	11.3	16.0	27.1	9.2	17.9		x	
41	N1684		x	90.1	81.5	8.6	90.2	82.3	7.9	90.2	81.9	8.3			x	21.9	6.6	15.3	22.4	5.0	17.4	22.2	5.8	16.4		x	
42	N1688	x		91.7	86.5	5.2	87.3	84.2	3.1	89.5	85.4	4.2			x	24.3	1.8	22.5	27.0	3.8	23.1	25.7	2.8	22.8			x
43	N1691	x		83.5	81.1	2.5	78.1	79.3	-1.2	80.8	80.2	0.7	x			20.7	2.1	18.6	27.7	5.8	21.9	24.2	4.0	20.3			x
44	N1697	x		83.4	79.5	3.9	79.9	76.8	3.1	81.7	78.2	3.5			x	39.5	4.8	34.7	41.1	9.1	31.9	40.3	7.0	33.3	x		
45	N1700	x		82.9	77.6	5.3	80.6	76.6	4.0	81.8	77.1	4.7			x	31.6	9.5	22.0	34.4	14.0	24.4	33.0	11.8	23.2			x
46	N1703	x		80.3	77.3	3.0	80.8	78.2	2.6	80.6	77.8	2.8		x		34.5	10.0	24.5	33.6	9.5	24.1	34.1	9.8	24.3			x
47	N1711	x		86.8	82.9	3.9	83.6	81.6	2.0	85.2	82.3	3.0		x		24.4	1.0	23.4	27.2	5.8	21.5	25.8	3.4	22.5			x
48	N1720	x		82.5	80.5	2.1	82.0	79.5	2.5	82.3	80.0	2.3		x		26.7	6.6	20.1	28.6	8.9	19.7	27.7	7.8	19.9			x
49	N1721	x		82.7	78.5	4.3	81.1	78.0	3.1	81.9	78.3	3.7			x	31.4	5.5	25.9	33.0	7.4	25.6	32.2	6.5	25.8			x
50	N1726	x		77.0	76.2	0.8	75.1	75.6	-0.5	76.1	75.9	0.2	x			29.1	8.5	20.6	29.8	10.0	19.8	29.5	9.3	20.2			x
51	N1839	x		78.4	77.8	0.6	80.6	80.9	-0.3	79.5	79.4	0.2	x			30.4	6.3	24.1	30.6	7.7	23.0	30.5	7.0	23.6			x
52	N1844	x		85.7	79.9	5.8	78.7	74.7	4.0	82.2	77.3	4.9			x	31.4	6.5	24.9	34.1	6.1	28.0	32.8	6.3	26.5			x
53	N1849	x		78.5	77.1	1.4	79.7	75.8	3.9	79.1	76.5	2.7		x		31.5	4.0	27.4	31.0	9.0	22.0	31.3	6.5	24.7			x
54	N1850	x		82.5	81.9	0.6	82.1	81.0	1.1	82.3	81.5	0.9	x			25.2	4.6	20.5	26.5	4.9	21.6	25.9	4.8	21.1			x
55	N1853		x	87.7	81.6	6.1	89.8	81.3	8.5	88.8	81.5	7.3			x	31.6	7.0	24.6	33.5	13.7	19.8	32.6	10.4	22.2			x
56	N1854		x	80.2	76.0	4.2	79.4	76.0	3.4	79.8	76.0	3.8			x	23.3	4.3	19.0	21.7	4.2	17.5	22.5	4.3	18.3		x	
57	N1858	x		87.3	84.6	2.7	85.2	83.2	1.9	86.3	83.9	2.3		x		27.2	1.1	26.1	27.2	2.7	24.6	27.2	1.9	25.4			x
58	N1859		x	84.1	79.0	5.0	82.4	79.1	3.3	83.3	79.1	4.2			x	26.1	3.9	22.1	27.1	4.9	22.2	26.6	4.4	22.2			x
59	N1863	x		81.6	78.7	2.9	82.8	79.4	3.4	82.2	79.1	3.2			x	34.7	12.5	22.2	31.6	14.6	17.0	33.2	13.6	19.6			x
60	N1868	x		82.5	80.5	2.0	85.1	82.5	2.6	83.8	81.5	2.3		x		30.5	6.1	24.4	26.9	6.8	20.1	28.7	6.5	22.3			x

61	N1874	x		74.8	75.7	-0.9	73.4	74.4	-1.0	74.1	75.1	-1.0	x			36.4	6.4	30.0	37.4	8.0	29.5	36.9	7.2	29.8	x		
62	N1875		x	80.4	76.0	4.3	75.4	74.2	1.1	77.9	75.1	2.7		x		35.0	5.1	29.9	33.9	14.5	19.4	34.5	9.8	24.7			x
63	N1880	x		88.6	84.0	4.1	84.3	83.5	0.8	86.5	83.8	2.5		x		25.2	10.1	15.1	24.2	8.5	15.7	24.7	9.3	15.4		x	
64	N1881	x		78.1	74.2	3.9	79.6	75.2	4.3	78.9	74.7	4.1			x	35.9	10.5	25.4	33.0	12.8	20.2	34.5	11.7	22.8			x
65	N1885	x		84.9	84.1	0.8	84.8	81.6	3.2	84.9	82.9	2.0		x		30.2	8.9	21.3	30.4	13.2	17.2	30.3	11.1	19.3			x
66	N1886	x		83.0	80.2	2.8	84.8	81.3	3.5	83.9	80.8	3.2			x	31.4	5.9	25.5	27.8	8.2	19.5	29.6	7.1	22.5			x
67	N1889		x	83.2	80.1	3.1	82.0	79.9	2.1	82.6	80.0	2.6		x		30.2	4.4	25.8	29.5	5.6	23.9	29.9	5.0	24.9			x
68	N1890	x		87.6	81.5	6.1	83.6	78.9	4.7	85.6	80.2	5.4			x	31.1	8.8	22.3	32.6	13.2	19.5	31.9	11.0	20.9			x
69	N1891		x	81.5	76.6	4.9	81.5	76.8	4.7	81.5	76.7	4.8			x	32.0	8.7	23.3	31.6	15.9	15.7	31.8	12.3	19.5			x
70	N1895	x		86.9	81.5	5.4	79.7	75.8	3.8	83.3	78.7	4.6			x	20.5	5.9	14.6	26.3	11.1	15.2	23.4	8.5	14.9		x	
71	N1896		x	82.2	78.7	3.4	82.8	78.9	3.9	82.5	78.8	3.7			x	33.6	6.9	26.7	34.1	15.2	19.0	33.9	11.1	22.9			x
72	N1910	x		79.6	78.0	1.6	80.4	77.6	2.7	80.0	77.8	2.2		x		27.8	6.3	21.5	27.0	11.2	15.7	27.4	8.8	18.6			x
73	N1913	x		84.4	80.7	3.7	80.9	77.7	3.2	82.7	79.2	3.5			x	29.8	8.7	21.2	29.0	9.5	19.5	29.4	9.1	20.4			x
74	N1919		x	87.3	80.1	7.2	87.2	80.3	6.9	87.3	80.2	7.1			x	30.3	4.0	26.4	27.4	6.1	21.3	28.9	5.1	23.9			x
75	N2020	x		83.1	77.9	5.2	78.4	73.6	4.7	80.8	75.8	5.0			x	32.5	4.2	28.3	33.9	6.6	27.3	33.2	5.4	27.8			x
76	N2021	x		89.3	81.9	7.3	77.5	73.9	3.7	83.4	77.9	5.5			x	29.9	5.7	24.3	35.0	14.4	20.6	32.5	10.1	22.5			x
77	N2024		x	81.5	77.2	4.3	80.8	77.4	3.4	81.2	77.3	3.9			x	35.0	10.2	24.8	33.9	15.1	18.8	34.5	12.7	21.8			x
78	N2025		x	80.1	76.3	3.8	79.1	76.2	2.9	79.6	76.3	3.4			x	26.6	6.1	20.5	25.0	8.3	16.6	25.8	7.2	18.6			x
79	N2033	x		81.4	80.6	0.6	77.9	76.1	1.7	79.7	78.4	1.2	x			27.4	2.6	24.6	29.1	9.7	19.5	28.3	6.2	22.1			x
80	N2043	x		79.8	77.6	2.2	77.9	77.3	0.6	78.9	77.5	1.4	x			34.5	4.6	29.9	30.9	7.2	23.7	32.7	5.9	26.8			x
81	N2044	x		85.3	83.5	1.8	77.7	77.1	0.6	81.5	80.3	1.2	x			31.6	1.1	30.5	33.0	6.0	27.0	32.3	3.6	28.8	x		
82	N2051	x		80.6	79.7	0.9	83.5	81.9	1.6	82.1	80.8	1.3	x			34.2	7.4	26.8	29.7	7.0	22.8	32.0	7.2	24.8			x
83	N2052	x		82.2	82.0	0.2	78.4	80.2	-1.8	80.3	81.1	-0.8	x			17.9	9.6	8.4	20.9	10.0	10.0	19.4	9.8	9.2		x	
84	N2053	x		76.0	79.3	-3.3	77.6	78.0	-0.4	76.8	78.7	-1.9	x			33.0	5.0	28.0	34.0	15.6	18.4	33.5	10.3	23.2			x
85	N2061	x		79.3	78.0	1.3	77.3	75.4	2.0	78.3	76.7	1.7	x			26.6	2.7	23.9	27.9	6.4	21.5	27.3	4.6	22.7			x
86	N2062	x		85.7	78.3	7.4	82.8	78.1	4.6	84.3	78.2	6.0			x	31.9	11.3	20.6	34.1	12.2	22.0	33.0	11.8	21.3			x
87	N2065	x		82.1	80.4	1.8	83.5	81.8	1.7	82.8	81.1	1.8	x			23.1	4.3	18.8	27.3	6.0	21.3	25.2	5.2	20.1			x
88	N2070	x		86.1	81.9	4.2	83.5	80.6	2.9	84.8	81.3	3.6			x	25.9	6.9	19.0	28.9	7.2	21.7	27.4	7.1	20.4			x
89	N2073		x	81.3	77.7	3.6	80.9	77.8	3.1	81.1	77.8	3.4			x	24.9	5.7	19.2	26.5	4.8	21.7	25.7	5.3	20.5			x
90	N2076		x	83.2	78.4	4.8	85.1	80.5	4.6	84.2	79.5	4.7			x	27.3	7.7	19.5	26.5	7.9	18.7	26.9	7.8	19.1			x
91	N2082		x	75.3	75.4	-0.1	77.8	76.8	1.0	76.6	76.1	0.5	x			32.2	8.6	23.5	31.9	9.2	22.6	32.1	8.9	23.1			x
92	N2093		x	88.4	85.9	2.6	87.1	85.6	1.8	87.8	85.8	2.2		x		22.0	2.8	19.2	22.3	4.5	17.8	22.2	3.7	18.5		x	
93	N2108	x		81.3	80.9	0.3	73.0	73.2	-0.2	77.2	77.1	0.1	x			27.4	1.3	26.1	32.9	9.0	23.8	30.2	5.2	25.0			x
94	N2113	x		73.5	73.9	-0.3	75.9	74.6	1.3	74.7	74.3	0.5	x			33.2	8.1	25.0	31.9	9.6	22.4	32.6	8.9	23.7			x
95	N2222		x	76.6	73.1	3.5	75.3	73.9	1.4	76.0	73.5	2.5		x		30.6	4.4	26.2	32.4	6.3	26.1	31.5	5.4	26.2			x
96	N2225		x	86.6	79.0	7.6	84.6	78.1	6.5	85.6	78.6	7.1			x	28.1	6.8	21.3	27.3	5.9	21.3	27.7	6.4	21.3			x

97	N2227	x		84.6	81.6	3.0	84.4	81.6	2.8	84.5	81.6	2.9		x		33.5	6.0	27.6	30.8	6.0	24.8	32.2	6.0	26.2			x
98	N2229	x		83.7	81.6	2.1	83.9	82.9	1.0	83.8	82.3	1.6	x			25.6	4.6	21.0	27.4	7.8	19.6	26.5	6.2	20.3			x
99	N2238	x		79.6	81.5	-1.9	77.9	81.8	-3.1	78.8	81.7	-2.5	x			29.3	4.6	24.7	30.6	5.6	5.0	30.0	5.1	14.9			x
100	N2240	x		81.5	81.4	0.1	81.1	81.2	0.0	81.3	81.3	0.1	x			25.8	4.9	21.0	18.0	4.7	13.3	21.9	4.8	17.2		x	
101	N2247		x	87.3	78.0	9.4	89.0	78.7	10.2	88.2	78.4	9.8			x	31.9	5.2	26.8	31.5	5.7	25.9	31.7	5.5	26.4			x
102	N2251		x	79.0	76.9	2.2	77.5	76.1	1.4	78.3	76.5	1.8	x			26.9	6.8	20.0	25.9	6.6	19.3	26.4	6.7	19.7			x
103	N2279	x		84.3	78.5	5.8	84.3	78.8	5.6	84.3	78.7	5.7			x	30.0	4.3	25.7	28.0	8.0	19.9	29.0	6.2	22.8			x
104	N2283		x	82.0	77.1	4.9	80.2	76.7	3.6	81.1	76.9	4.3			x	33.7	6.7	26.9	33.5	7.8	25.7	33.6	7.3	26.3			x
105	N2286		x	83.0	77.2	5.8	80.4	77.2	3.2	81.7	77.2	4.5			x	27.9	7.9	20.1	27.8	6.7	21.1	27.9	7.3	20.6			x
106	N2292		x	81.4	76.5	4.8	79.6	76.5	3.1	80.5	76.5	4.0			x	27.8	6.8	21.0	28.5	11.2	17.3	28.2	9.0	19.2			x
107	N2298	x		82.9	80.8	2.1	82.4	81.2	1.3	82.7	81.0	1.7	x			32.3	5.4	26.9	29.3	5.7	23.6	30.8	5.6	25.3			x
108	N2304	x		79.5	77.3	2.2	78.1	77.2	0.9	78.8	77.3	1.6	x			35.5	7.6	27.9	32.1	7.3	24.8	33.8	7.5	26.4			x
109	N2305		x	84.3	78.1	6.1	81.3	77.4	3.9	82.8	77.8	5.0			x	25.6	7.1	18.5	28.1	8.3	19.9	26.9	7.7	19.2			x
110	N2612	x		82.3	80.2	2.1	81.0	81.5	-0.5	81.7	80.9	0.8	x			26.3	5.1	21.2	25.1	6.8	18.3	25.7	6.0	19.8			x
111	N2613	x		84.7	81.7	2.9	86.3	81.9	4.4	85.5	81.8	3.7			x	34.9	6.7	28.2	34.5	8.3	26.2	34.7	7.5	27.2			x
112	N2614		x	77.3	74.0	3.3	76.8	74.2	2.6	77.1	74.1	3.0		x		30.8	7.5	23.3	32.5	8.8	23.7	31.7	8.2	23.5			x
113	N2624		x	85.5	79.0	6.5	86.9	79.9	7.0	86.2	79.5	6.8			x	33.6	9.1	24.5	33.7	11.1	22.5	33.7	10.1	23.5			x
114	N2627	x		83.0	81.0	2.0	83.1	80.8	2.3	83.1	80.9	2.2		x		31.7	4.0	27.7	27.7	4.6	23.2	29.7	4.3	25.5			x
115	N2634		x	86.8	78.0	8.8	85.1	77.2	7.8	86.0	77.6	8.3			x	27.8	5.1	22.7	32.6	5.8	26.8	30.2	5.5	24.8			x
116	N2635		x	81.3	77.5	3.8	77.7	75.4	2.3	79.5	76.5	3.1			x	30.3	7.6	22.6	32.7	9.7	23.0	31.5	8.7	22.8			x
117	N2642	x		80.0	77.1	2.9	77.1	77.0	0.1	78.6	77.1	1.5	x			32.6	11.3	21.3	31.2	12.6	18.6	31.9	12.0	20.0			x
118	N2645		x	81.8	79.2	2.5	78.6	78.6	0.0	80.2	78.9	1.3	x			24.8	8.1	16.7	26.1	10.4	15.6	25.5	9.3	16.2		x	
119	N2652		x	85.0	79.0	6.0	81.8	77.9	3.9	83.4	78.5	5.0			x	27.7	9.0	18.8	25.5	9.7	15.7	26.6	9.4	17.3		x	
120	N2663		x	84.1	75.2	8.9	83.2	74.0	9.2	83.7	74.6	9.1			x	34.0	8.0	26.0	38.0	10.0	28.0	36.0	9.0	27.0			x
121	N2664		x	87.4	78.7	8.7	85.5	78.2	7.3	86.5	78.5	8.0			x	30.2	6.0	24.2	31.5	7.7	23.9	30.9	6.9	24.1			x
122	N2671		x	84.0	79.4	5.6	82.0	77.4	4.6	83.0	78.4	5.1			x	30.3	10.8	19.5	31.7	10.4	21.3	31.0	10.6	20.4			x
123	N2679	x		81.4	78.7	2.7	85.2	82.9	2.3	83.3	80.8	2.5		x		30.0	5.2	24.8	24.2	3.0	21.2	27.1	4.1	23.0			x
124	N2685	x		83.5	82.0	1.5	83.8	83.9	-0.1	83.7	83.0	0.7	x			25.8	7.3	18.5	21.4	7.3	14.1	23.6	7.3	16.3		x	
125	N2697		x	81.2	78.1	3.1	78.2	76.5	1.7	79.7	77.3	2.4		x		25.5	4.4	21.1	26.2	7.4	18.7	25.9	5.9	19.9			x
126	N2700	x		85.0	80.7	4.4	88.1	83.1	5.0	86.6	81.9	4.7			x	32.8	4.9	27.9	28.3	5.1	23.2	30.6	5.0	25.6			x
127	N2788		x	84.8	75.5	9.3	85.0	74.9	10.1	84.9	75.2	9.7			x	36.0	9.5	26.6	39.1	13.5	25.6	37.6	11.5	26.1			x
128	N2810		x	80.8	76.0	4.9	78.2	74.9	3.3	79.5	75.5	4.1			x	22.2	6.0	16.2	26.8	9.8	17.0	24.5	7.9	16.6		x	
129	N2813		x	83.5	77.5	6.0	81.8	77.3	4.5	82.7	77.4	5.3			x	29.4	3.2	26.3	32.8	5.8	27.0	31.1	4.5	26.7			x
130	N2820		x	83.2	81.6	1.7	78.5	79.4	-1.0	80.9	80.5	0.4	x			24.8	5.7	19.2	26.0	7.9	18.1	25.4	6.8	18.7			x
131	N2824		x	82.4	77.1	5.3	80.0	76.7	3.3	81.2	76.9	4.3			x	29.7	10.5	19.2	30.5	11.0	19.5	30.1	10.8	19.4			x
132	N2831		x	83.1	77.9	5.2	81.5	77.8	3.7	82.3	77.9	4.5			x	29.6	10.3	19.3	30.4	12.3	18.0	30.0	11.3	18.7			x

133	N2839		x	85.3	81.0	4.2	82.6	81.3	1.3	84.0	81.2	2.8		x		19.9	6.4	13.5	21.6	7.0	14.6	20.8	6.7	14.1		x	
134	N2846		x	84.5	81.7	2.8	81.7	81.0	0.6	83.1	81.4	1.7	x			20.3	4.4	15.9	21.7	4.7	17.0	21.0	4.6	16.5		x	
135	N2849		x	76.8	73.8	3.0	73.3	73.6	-0.2	75.1	73.7	1.4	x			32.9	5.9	27.1	34.6	5.0	29.6	33.8	5.5	28.4			x
136	N2852		x	83.5	78.4	5.1	81.4	78.3	3.0	82.5	78.4	4.1			x	25.4	6.7	18.7	25.7	6.5	19.2	25.6	6.6	19.0			x
137	N2866		x	81.3	77.7	3.5	79.1	76.6	2.5	80.2	77.2	3.0		x		29.9	10.0	20.0	30.6	8.9	21.7	30.3	9.5	20.9			x
138	N2871		x	83.5	81.0	2.5	81.1	80.4	0.7	82.3	80.7	1.6	x			25.5	-1.9	27.5	26.2	0.6	25.7	25.9	-0.7	26.6			x

n class I=77
n class II =61
n total=138

Attachment 1 table: Full table of tracing results adapted from FACAD®. 77 children with Angle Class I molar relationship, 61 children with Angle Class II molar relationship and in total of 138 children. Registered mean average of the tracing performed by the authors, in both sagittal- and vertical dimensions. id: identification, Nit.id: Nittedal patient identification, Angle Class I: First molar relationship; the mesiobuccal cusp of the maxillary permanent first molar occludes in the occlusal groove of the permanent first molar in the mandibula. Angle Class II: First molar relationship; the lower arch first permanent molar locking more than one-half of a cusp distal to normal relation with the upper first permanent molar. SNA: Sella-Nasion-A-point, SNB: Sella-Nasion-B-point, ANB: A-point-Nasion-B-point. R: Retrognathic, O: Orthognathic, P: Prognathic, ML/NSL: The angle between mandibular-line and sella-nasion-line. NL/NSL: The angle between nasal-line and sella-nasion-line. ML/NL: The angle between mandibular-line and nasal-line. Hyperdivergent: increased angular relationship in the basal vertical plane. Hypodivergent: decreased angular relationship in the basal vertical plane. Normal: normal angular relationship in the basal vertical plane.

Sagittal basal relation (n)	**Class I**	**Class II**
Prognathism	30	44
Retrognathism	31	7
Orthognatism	16	10
n total	**77**	**61**

Attachment 2: Full table showing the different sagittal basal relations in both the Angle class I and Angle class II cumulative subject's specimens.

Vertical basal relation (n)	**Class I**	**Class II**
Hyperdivergent	5	1
Hypodivergent	9	14
Normal	63	46
n total	**77**	**61**

Attachment 3: Full table showing the different vertical basal relations in both the Angle class I and Angle class II cumulative subject's specimens.