Die Synchondrosis Spheno-Basilaris (SSB) als zentrales Element der Schädelbasis

Master Thesis zur Erlangung des Grades

Master of Science in Osteopathie

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Title: The Sphenobasilar Synchondrosis (SBS) as a central part of the base of the skull

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1. Introduction:

There is hardly a theme in the osteopathic context which is that much in discussion than the cranial concept, based on the investigations and publications of W. G. Sutherland.

He was a student of A.T. Still, the founder of osteopathy. In the beginning of the last century he created a new concept based on the fundaments of Stills ideas and philosophies. Dr. Sutherland introduced the cranial concept; he drew on his many years of study and clinical practice, to base it on 5 fundamental physiological principles. Nowadays, the cranial concept can be considered as more or less the third "pillar" aside the structural and visceral concept in osteopathic science and teaching (WSO, 2007).

One of Stills principles – the holistic viewing of patient – is extraordinary represented in the cranial concept (Still, 1895). Nevertheless it is supposed controversially and doubtfully for lack of scientific findings (Baker, 1971 - Frymann, 1966 - Retzlaff, 1975 - Tettambel, 1978 - Rommeveaux, 1992 - Adams et al. 1992 - Hartmann, 2006).

Also numerous results of studies do not support the hypotheses behind the cranial concept (Rogers et al., 1998 - Moran & Gibbons, 2002 - Sommerfeld, 2006). For that reason, there is a high motivation to deal with this topic, and to work out scientific contributions in the way of a master thesis.

My work deals with a "central part" in multiple respects. The base of the skull is an important area for some bearing and steering elements of the body. It is fundament for the brain and numerous bones, and origin of numerous muscles, ligaments and fascias (Putz, 2004).

From an embryological viewpoint there is an elementary importance of the protecting function for essential parts of the body like cranial nerves, arteries or the brain stem (Drews, 2006 - Augustin, 2007).

The sphenobasilar synchondrosis (SBS) is the central part of the skull base itself.

It has an outstanding importance in cranial osteopathic concept concerning the mechanics of bones of the skull, and also in treatment of patients (Becker, 1997).

In an osteopathic view, any changes in this "key-part" have an effect all over the rest of the body (Liem, 2005).

Sutherland describes these consequences for the first time in his book "The Cranial Bowl" (Sutherland, 1940). It took him thirty years to work out his findings.

His student, Harold Magoun, continued his work. He specified and illustrated the knowledge of Sutherland in his book "Osteopathy in the Cranial Field" (Magoun, 1966).
Up to now, we can find this ideas and concepts in teaching books (Liem, 2005 – Upledger, 2000) and in master thesis (Krenner, 2007). In osteopathic discourse alterations at SBS are called strains (Sutherland, 1990). That means loss of (intra-osseous) flexibility, and not a mechanical movement (shift) in a narrow sense (Liem, 2005). But as a result of this study you might be taken aback to find changes in position (not in movement!) of SOS that can be interpreted as a real displacement.

There are numerous but partly very old radiological studies about the base of the skull (Long, 1971 - Ingervall, 1972 - Melsen, 1968 et 1972). The purpose of these investigations can be summarized to few aspects. The main effort in scientific works is to find out time of ossification of the bones (Thilander, 1973 - Furuya, 1984 - Ebel, 1985) and closure of SBS. In 1963, Powell and Brodie investigated for the first time 205 males 8 to 21 years and 193 females 6 to 18 years of age by means of midsagittal laminagraphy. In general, the closing age for the males was between 13-16 years, and the female between 11-14 years (Powell et al., 1963). There is a high accordance as concerns the time of closure of SBS with later studies using computed tomography (CT) (Virapongse, 1985 - Meneses, 1994 - Madeline, 1995 - Okamoto, 1996 - Adem et al., 1999) or magnetic resonance scans (MR) (Nakamura, 1996 - Oyar, 1996). In 2005, Schalkhaußer found 11 experimental studies in a systematic review that proved to be relevant for closure and mobility of the spheno-occipital synchondrosis. All of them agreed in that the spheno-occipital synchondrosis closes during adolescence or early adulthood. Nine studies report on sex as a predictor of time of closure, and on marked interindividual variation. In none of the studies closure started before the age of 8, but in all studies definite closure corresponds well with puberty. Out of a total number of 1469 cases studied there were only two persons (0.14%) with their synchondrosis remaining at least partially open after puberty. None of the studies commented on persisting mobility of the spheno-occipital synchondrosis (Schalkhaußer, 2005).
Some authors wrote about the morphology of this area – partly combined with clinical aspects (Ericson, 1973 - Wackenheim, 1985 – Molsted, 1995 – Kaufman, 1995 - Elmaleh et al., 2003).
Also the expansion and reduction in aeration of the sphenoid Sinus has been experienced in 2000 by means of Helical CT (Yonetsu, 2000).

Finally a lot of studies were done on the skull base of animals like rabits, rats, dogs and apes (Adams, 1972 - Dolan, 1971 - Michael, 1975 - Sawin, 1959 - Giles, 1981 - Roberts, 1975 - Heinkele, 1989 - Rosenberg, 1997 - Nakamura, 1999 etc.).
After a long and intensive research I could not find out any study about the variation of position or movement of the SBS as it has been instructed in our osteopathic school and as it is described in osteopathic teaching books (Magoun, 1966 - Liem, 2005 – Upledger, 2000).

Consequentially, our research question was, if it is possible to find shifts at the SOS which can be determined by means of computed tomography in sagittal plane.
In a second step we tried to assess the degree of alteration by using helical CT scanning. For the first time it is possible to start a research upon this specific question in cooperation with the Department of Radiology at the Elisabethinen-Hospital in Linz. When starting this challenge, even experienced radiologists could not apprise, if it is possible to identify shifts or strains from the SBS in sagittal plane.

2. Basics

2.1. Osteopathic view of the SBS

The SBS plays an important part in cranial osteopathic concept. This extraordinary position is based on embryological and anatomical facts. Moreover the physiology of the area around and even for the rest of the body depends on this "joint" (see introduction).

Sutherland describes the movement of cranial bones as well as the consequences for the rest of the body in a logical way. His thoughts are based on the hypothesis, that there is a cranial rhythmic impulse also called Primary Respiratory Mechanism (PRM) aside the well-known rhythms of the heart, the breathing or the autonomic movement of the intestines and other tissues.

Up to our days, there is no scientific interpretation of this involuntary very subtle and smooth "movement". There are some concepts about the PRM. They are based on biomechanical studies of cerebro-spinal fluid (CSF) pulsation waves (Upledger, 2000), neural envelopes and studies of physiologic factors which influence vessel wall tonus (Norton, 1991). The difference between the rhythm of venomotion and the cerebro-spinal fluid is suggested that PRM is probably the expression of Local Venomotion and not of CSF pulsations or the consequences of it (Farasyn, 1999).

On the whole the existing material, assessing the reliability of cranial findings, is not very extensive and moreover divergent. Several methodological aspects can be criticised in these studies (Green, 1999 - Sommerfeld, 2006). This is the reason for disapprobation of the cranial osteopathy by scientific thinking persons.

On the other hand there are detailed and logical descriptions from Sutherland and his successor. Even clinical aspects and pathological changes are described. They are summarised in chapter 2.1.4.

2.1.1. Anatomy

The SBS is formed by two bones:

A) Os sphenoidalis

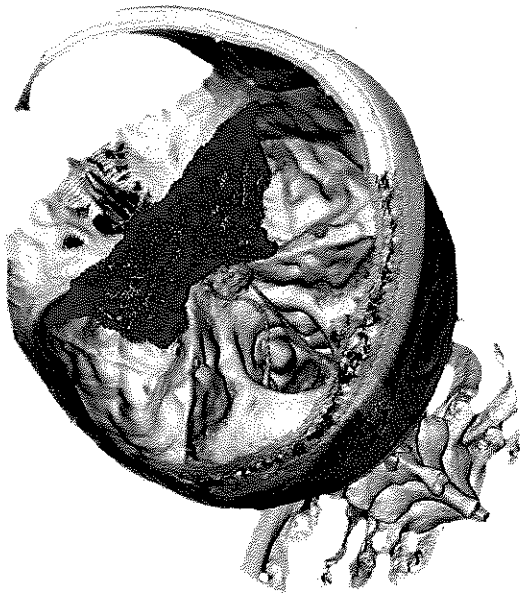


Fig. 1: *Sphenoid (blue area)*
(view from above to inner side)

B) Os occipitalis

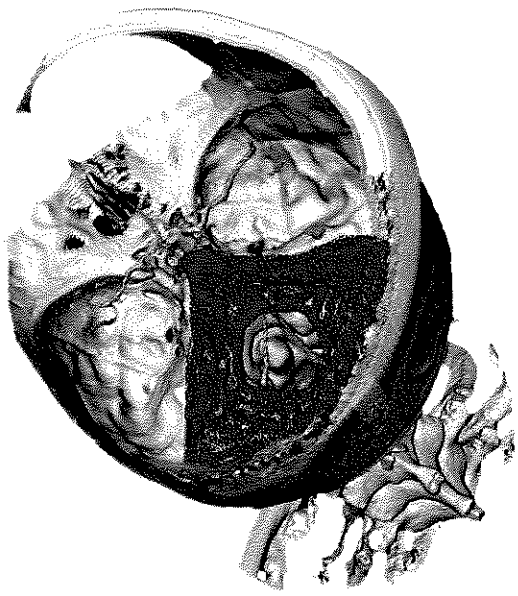


Fig. 2: *Occiput (blue area)*

The connection of the pars basilaris of the occiput (basi-occiput) and the corpus of the sphenoid (basi-sphenoid) is called sphenobasilar synchondrosis (SBS)
At women it ossificates with the age of 11 to 14, and between 13 and 16 at men (Powell, 1963).

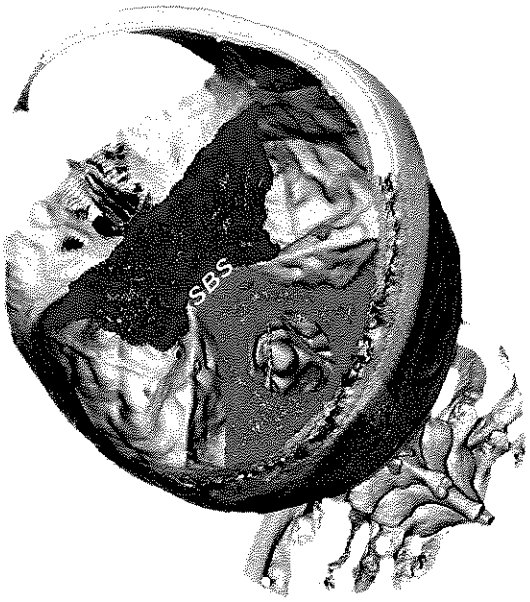


Fig. 3: *SBS at the crossing of blue area (sphenoid) and red area (occiput)*

The SBS is situated on a level with symphysis mentalis and vertex.

The reciprocal tension membrane (dura mater) inserts on both bones and is connected functionally.

Os sphenoidalis articulates with 12 other bones, os occipitalis with six.

2.1.2. Physiological pattern

Sutherland describes a mechanics of SBS similar to movements of the spine (Sutherland, 1940). He compares os sphenoidale, os occipitale and os temporale with a segment of the spine, whereas os temporale can be considered as a rip.

He differs from physiological und aphysiological pattern. The difference between these two categories is mostly the fact, that there is no deviation of the centreline of the bones at physiological pattern. Notation accords to direction of movement of the sphenoid bone. For better understanding I like to introduce a figurative presentation of different possibilities of movement. But again it must be mentioned, that this concept is still in use for teaching and didactical interpretation of cranial osteopathy. The hypotheses of cranial mobility and the existence of the PRM cannot be regarded as scientifically proven.

The physiological flexion and extension of the SBS is one component out of five of the Primary Respiratory Mechanism. In cranial concept it exists as long as there is life.

A) *Flexion:* The basi-sphenoid goes up cranially as well as the basi-occiput

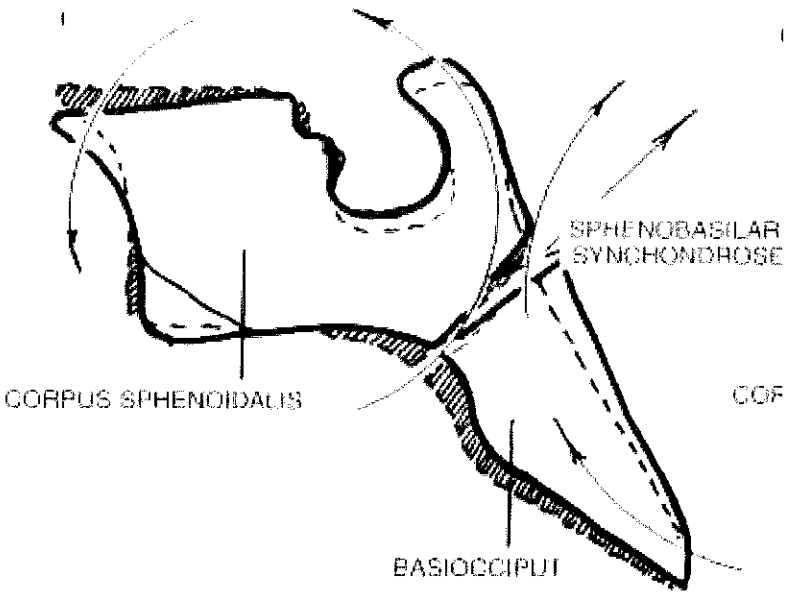


Fig. 4: *Flexion*

B) *Extension:* the basi-sphenoid goes down (caudally) as well as basi-occiput

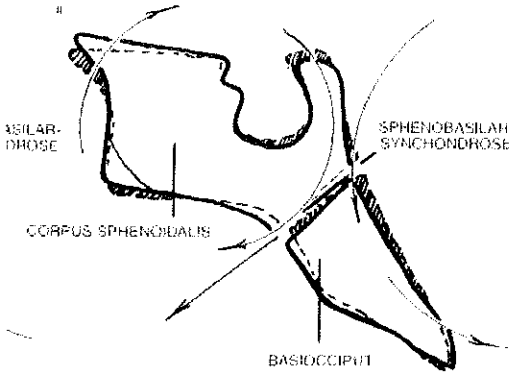


Fig. 5: *Extension*

B) *Torsion:* one part turns left or right – or both parts to the opposite side

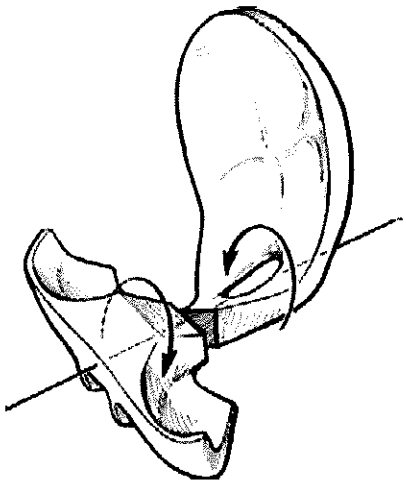


Fig. 6: *Torsion*

C) *Sidebending/Rotation:* combined movement of the SBS

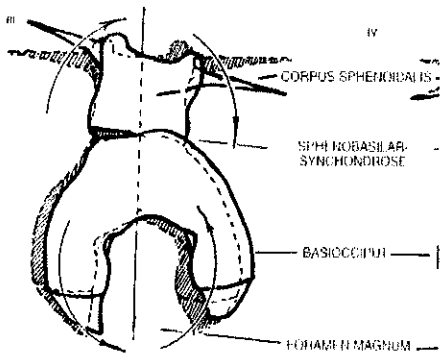


Fig. 7: *Sidebending-Rotation*

2.1.3. Aphysiological pattern

Involuntary mechanism is frequently modified by impairments of mobility of the SBS or other bones of the skull.

If there is a trauma (perhaps beginning with birth or even intrauterine) in time before closure of the SBS there will be (morphological) changes similar to what we know from the spine (listhesis). A tough force after this procedure can cause alterations as well (fracture of skull base). The centreline of the two bones is displaced, there will be a shift. The notation accords to the direction of deviation of sphenoid bone (equal to all other patterns).

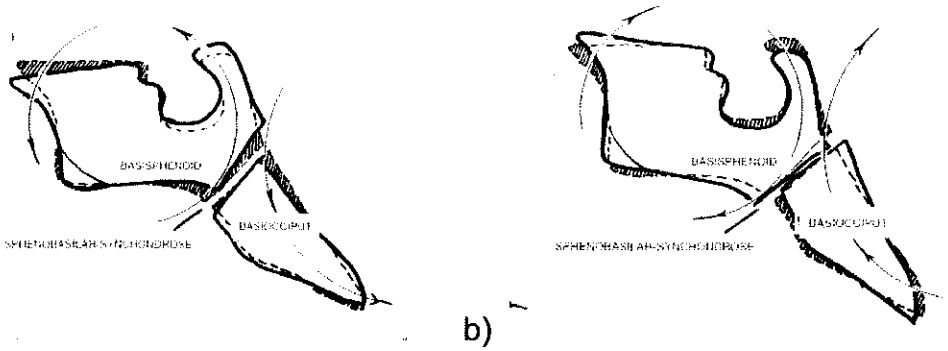
Consequently we can find two kinds of strains (vertical, lateral) in two directions either. Corpus of sphenoid can be displaced up or down respectively left or right relating to basi-occiput. An upshift is called "superior vertical strain" (Fig. 8a), the downshift is denominated "inferior vertical strain" (Fig.8b). If sphenoid is left in regard of occiput, it is described as a "left lateral strain" (Fig.9a) and vice versa (Fig. 9b).

Another possibility of alternation to the SBS is compression (Fig.10) or traction (Fig.11). Under certain circumstances (rough force, trauma, birth etc.) the two bones can be pushed together or separated. Unfortunately compression can accumulate an existing pattern especially when growing up. Traction means, that there is an incomplete closure of the SBS when growing up, or a bigger separation in younger years.

Last but not least we have to deal with intraosseous lesions. These are all kinds of morphological changes in the bone itself, according to the osteopathic principle "form governs function".
These patterns and variations are aphysiological, but they can be tolerated to a certain degree without disturbing important functions and parts of the body.

Up to now there is no scientific evidence for this cranial mobility or alteration of position. Therefore this master thesis can be a first step in verifying at least changes in position of SBS. There will be no reference to movement. I exclusively deal with strains and displacements that can be illustrated in a sagittal reformatted CT-image.

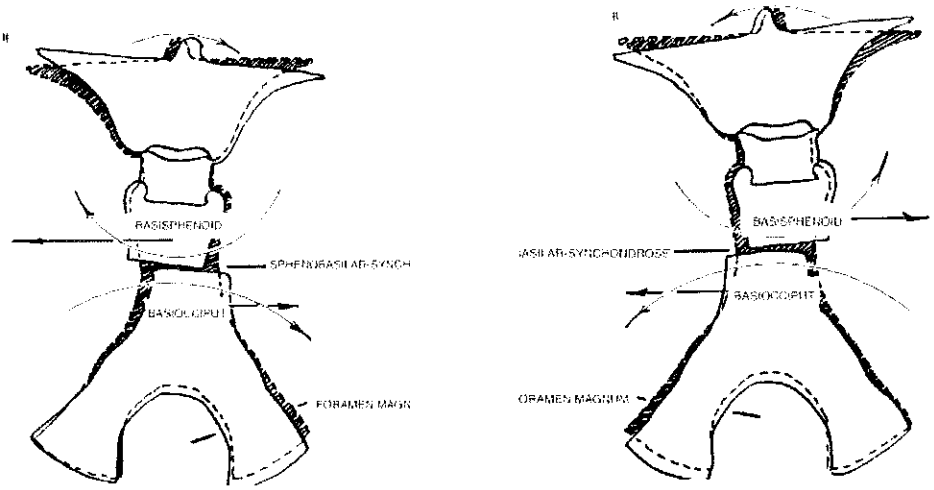
A) ***" vertical strain" :*** shift of the SBS cranially or caudally, when the sphenoid goes into flexion and occiput goes into extension



a) b)

Fig. 8 (a,b): *Vertical strain*

B) ***"Lateral strain" :*** shift of the SBS left or right



a) b)

Fig. 9 (a,b): *Lateral strain*

C) ***"Compression" :*** more or less restricted mobility because of a compression of the two bones

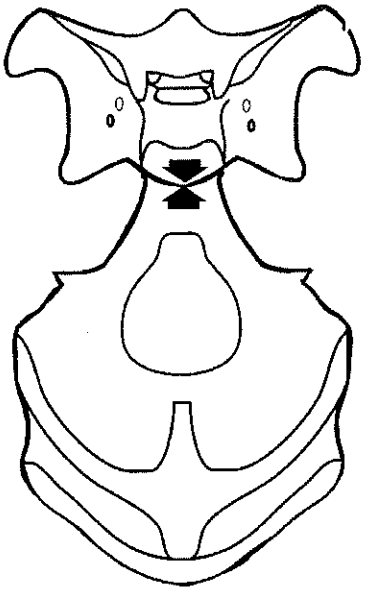


Fig. 10: *Compression*

D) ***"Traction" :*** incomplete Closure of the SBS with a gap between the two bones

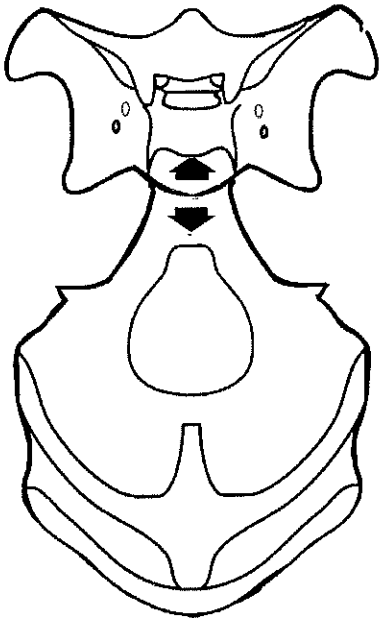


Fig. 11: *Traction*

2.1.4. Clinical aspects of the SBS

Movement of all bones of the skull depends directly or indirectly from sphenoid and occipital bone. Also a pattern of sutured and/or membranous lesion is directed by these two central bones.
It should be mentioned, that this concept of human physiology in reference to clinical aspects is not validated scientifically yet (Magoun, 1965 - Sommerfeld, 2006). I also like to mention, that this master thesis cannot give evidence of clinical aspects. My only intention for this description is to demonstrate the importance of this area.
In Sutherlands collected writings we can find connections and results of changes in the SBS. He worked out his concept over a period of 30 years partly in self-experiments. By using helmets and belts he induced pathologies, and he was able to remediate the symptoms with his unique (mechanical) understanding afterwards. His findings are described impressively and summarized below (Sutherland, 1914).

There is a link of the SBS with the most vital parts of nervous system.
The control of voluntary motion with the muscular, sensitive and motoric system is located around sulcus centralis (Fissura of Rolando). This area is supplied with blood only from arteria cerebralis media, which runs along the border of lesser wing of sphenoid. There can be a direct mechanical influence or a vasomotor reflex on this blood vessel, especially caused by sidebending/rotations and torsions of the SBS.
These lesions also have an influence on fluctuation of cerebra-spinal fluid in subarachnoid space.
Corpus callosum, which is located in the centre of cerebral hemisphere, is also supplied with blood from arteries nearby the corpus of sphenoid. Venous sinus drainage of this area is via sinus cavernosus and sinus rectus.
Physiological disorders concerning the basal ganglia effects in rigidity of muscles and tremor. Therefore anomalies of position of the SBS with strains of tentorium cerebella have far-reaching consequences. Even thalamus, placed between the sidewalls of third ventricle, can be affected. That means dysfunction in transmission and emission of sensible information of the whole system.

Cranial of the SBS we can find the closely attached midbrain with a length of about 2.5 cm. All connections between cortico-cerebral centres and spinal chord proceeding to the rest of the body run through the midbrain. Consequently, a movement of sphenoid and/or occiput has a great amount for this region.

Other structures like nasopharynx, falx cerebri, venous sinus, arteries or the subarachnoidal space are at the same level.

At cadavers Sutherland could see that aquaeductus cerebri can be totally closed when SBS is in torsion. It can be snapped off when the SBS is in side bending/rotation.

There is also the possibility that foramen interventriculare (Monro) is blocked on one side. It has been seen in autopsy that this closure leads to a unilateral hydrocephalus. Concerning falx cerebri, which inserts in its central part on sphenoid and occiput, it seems to be obvious, that torsion lesions can cause multiple functional restrictions of the reciprocal tension membrane. The venous sinus drainage depends on this structure. A stasis in blood-flow can cause severe damage to central nervous system.

A restricted mobility of the SBS can result in a dysfunction of structures at the base of forth ventricle.

Hypothalamus, located underneath the third ventricle, commands some essential function of the body like the autonomic nervous system, temperature regulation, blood pressure, sleep-wake rhythm, feeling of hunger and so on.

Side bending/rotation of the SBS can compress Hypothalamus and interfere with its function.

Pituitary gland is fixed in the sella turcica of sphenoid bone. It is the central part of all endocrine reactions. For a good work there should be a physiological mobility of the SBS. Otherwise a reduced activity can influence the metabolism, the process of growth, menstruation and a lot of other functions of the body. A drastic reaction is known from a treatment of labour pains weakness.

Each of the twelve cranial nerves can also be influenced: Nervus olfactorius when passing the lesser wing of the sphenoid, Nervus opticus in the optic channel or above the body of the sphenoid. Oculomotor nerv, trochlear nerv, opthalmic nerv and abducens nerv can be irritated because of an unphysiological tension of sphenopetrosa ligament or at fissura orbitalis superior. Nervus maxilaris, which runs through foramen rotundum, nervus mandibularis in foramen ovale, nervus facialis and vestibulocochlearis when passing meatus acusticus internus, the three nerves of jugular foramen (nervus glossopharyngeus, nervus vagus and nervus accessories), and nervus hypoglossus who goes off canalis hypoglossus are other cranial nerves that can be irritated by membranous or osseous strains. Nerves and blood vessels

are covered by dura mater. They are very sensitive when passing the cerebral foramen (Page, 1952).

The greater wing of sphenoid can influence the sense of tasting, hearing or smelling. For right-handed people the lesser wing on the left side can cause a motor aphasia when irritating the Broca area.
Visual centre is nearby occiput. A compression of squama occipitalis can result in myopia.
Lesions of the SBS often come up with headache, paralyses of facials nerve, increase of salivating, astigmatism, vertigo, hypertension, sinusitis etc. Patients with migraine only on one side have their greater wing up on the affected side. Tension of membrane changes and influences the circulation of fluids. Especially the drainage through jugular foramen, where 95 % of venous blood of the skull passes, is important for homeostasis.

In conclusion all these facts show the importance of the SBS concerning on the one hand the position and on the other hand the movement of this central part. Nevertheless this knowledge is not validated scientifically yet, as mentioned above.

2.2. Radiological basics of computed tomography

2.2.1 Preface

Computed tomography (CT) is one of four methods of radiology (apart from ultrasonography, magnetic resonance and X-ray)
It is used in medicine as a diagnostic tool, for planning and controlling the treatment and as a guide for interventional procedures. Sometimes contrast materials such as intravenous iodinated contrast are used. This is useful to highlight structures such as blood vessels that otherwise would be difficult to delineate from their surroundings. Using contrast material can also help to obtain functional information about tissues.

By scanning patients it is possible to illustrate non-visible structures without offending any structure. There can be generated views of the human body, which are reserved for surgeon, pathologist or dissectors only. It is a highly recommended method for clinical use but also for basic researches. Therefore also osteopaths can benefit from using CT in their work.

In 1972 the american physicist A.M. Cormack and the british engineer G.N. Hounsfield presented the operation of CT for the first time. Seven years later they earned the Nobel Prize for medicine for their contrivance.
There was a very fast development of equipment. In 1989 the first helical CT scanning could be realised (Kalender, 1990 – Crawford, 1990). Four years later the first multi-slice scanners were introduced followed by Dual Source scanners in 2005. Consequently, the duration of analyses could be reduced and the presentation of the scanning became more precise and specific. Although still quite expensive, it is the gold standard in diagnosis of a large number of different disease entities.

It is the combination of high-capacity x-ray tubes, new technologies like electron beam tomography and better algorithms of data analysis that makes radiology to a fast-developing and innovative field in general medicine.

2.2.2. Particularities

The purpose of CT is to create cross sections of the human body. X-ray slice data is generated using an X-ray source that rotates around the object. X-ray sensors are positioned on the opposite side of the circle from the X-ray source. Many data scans are progressively taken as the patient is gradually passed through the gantry. They are combined together by the mathematical procedure known as tomography reconstruction.

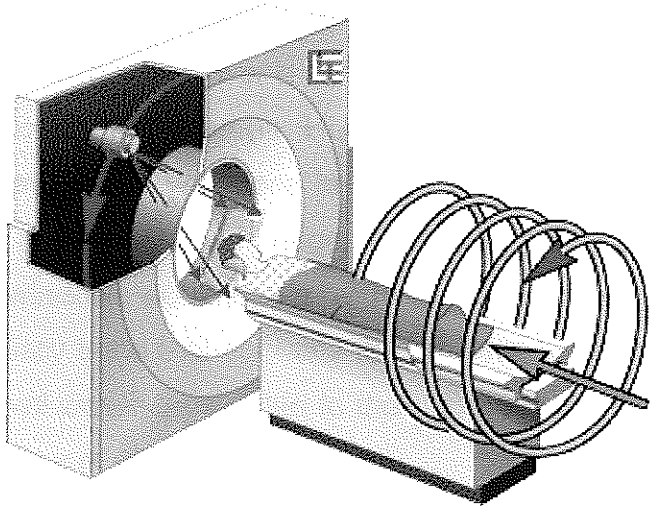


Fig. 12: *Computed Tomography*

Newer machines with faster computer systems and newer software strategies can process not only individual cross sections but continuously changing cross sections as the gantry, with the object to be imaged, is slowly and smoothly slid through the X-ray circle. These are called helical or spiral CT machines. Their computer systems integrate the data of the moving individual slices to generate three-dimensional volumetric information (3D-CTscan). Pictures are viewable from multiple different perspectives on attached CT workstation monitors.

The data stream representing the varying radiographic intensity is then computer processed to calculate cross-sectional estimations of the radiographic density, expressed in Hounsfield units (HU). Sweeps cover 360 or just over 180 degrees in conventional machines (Dössel, 2000).

Pixels in an image obtained by CT scanning are displayed in terms of relative radio density. The pixel itself is displayed according to the mean attenuation of the tissue(s) that it corresponds to on a scale from -1024 to +3071 on the Hounsfield

scale. It is a two dimensional unit based on the matrix size and the field of view. Water has an attenuation of 0 Hounsfield units while air is -1000 HU, cancellous bone is typically 400 HU, cranial bone can reach 2000 HU or more (os temporale) and can cause artifacts (Reiser, 2006).

Windowing is the process of using the calculated Hounsfield units to make an image. The various radiodensity amplitudes are mapped to 256 shades of gray. These shades of gray can be distributed over a wide range of HU values to get an overview of structures that attenuate the beam to widely varying degrees. Alternatively, these shades of gray can be distributed over a narrow range of HU values (called a "narrow window") centered over the average HU value of a particular structure to be evaluated. In this way, subtle variations in internal makeup of the structure can be discerned. This is a commonly used image processing technique known as contrast compression. Bone windows would use a "wide window" (to evaluate everything from fat-containing medullary bone that contains the marrow, to the dense cortical bone), and the center or level would be a value in the hundreds of Hounsfield units. In this study we used a window of 400 and 1800 HU.
Processing will most likely take between five minutes and one hour.
First, CT completely eliminates the superimposition of images of structures outside the area of interest. Second, because of the inherent high-contrast resolution of CT, differences between tissues that differ in physical density by less than 1% can be distinguished. Third, data from a single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal, or sagittal plane, depending on the diagnostic task. This is referred to as multiplanar reformatted imaging.

CT is regarded as a moderate to high radiation diagnostic technique. The greatly increased availability of CT, together with its value for an increasing number of conditions, has been responsible for a large rise in popularity.
While technical advances have improved radiation efficiency, there has been simultaneous pressure to obtain higher-resolution imaging and use more complex scan techniques, both of which require higher doses of radiation.

3. General Methodology

3.1. Materials and methods

When starting our work we wanted to know, if it is possible to find shifts at the SBS which can be determined by means of computed tomography in sagittal plane.
In matter of finding relevant changes we tried to assess the degree of alteration in a second step. This study could be realised at the Elisabethinen hospital (Linz) in cooperation with the Department of Radiology. The purpose was to demonstrate displacements/shifts at the SBS by means of CT imaging system in sagittal plane.

We worked out images of the SBS in sagittal plane for a period of more than a year. Selection of cases was randomized but limited to patients with ear, nose and throat problems. The reason for it was that we used paranasal sinuses CT images (PNS-CT). Usually conventional "head CT" are made for diagnosis of cerebro-vascular accidents and intracranial haemorrhage. Scanning is done with or without intravenous contrast agents. Bony structures are normally not well represented except when using CT in the setting of trauma for evaluating facial and skull fractures. In the face/mouth area, CT scanning is used for surgical planning for craniofacial and dentofacial deformities, evaluation of cysts and some tumors of the jaws/paranasal sinuses/nasal cavity/orbits, diagnosis of the causes of chronic sinusitis, and for planning of dental implant reconstruction. In opposite to a common head CT the bony structures are in interest to investigations.
Therefore we used paranasal sinuses CT images for our study. The illustration of the whole skull base (Os occiptalis inclusive) is warranted. Usually PNS-CTs are allegorized only in coronal and transverse plane. To verify superior or inferior strains of the SBS it is necessary to get sagittal images. This level was reconstructed separately for this study. There was no higher dose of radiation for the patients or a longer examination procedure because all calculations were done with the basic data afterwards. Patients were examined in a common clinical procedure during their stay in hospital. They did not know anything about this study.

We retrospectively reviewed helical CT images of 138 patients in total (age range, 20 to 86 years; 75 male (average age: 46.4) and 63 female subjects (46.6). All patients come from various departments of the hospital. The main part (95 persons or 68.8%) is from the Department of otolaryngology. The request for a CT examination comes

from otorhinolaryngologists according to underlying disease (mostly sinusitis, headache and allergy).

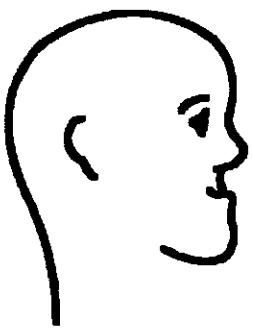
We used a HiSpeed Advantage SG CT imaging system (Thoshiba Aquilion S16 scanner). Scanning orientation was parallel to Frankfurt horizontal line. Scanning was performed with a collimation of 3 mm section thickness, a pitch of 1:1, a 512 x 512 matrix; a display field of view of 23 cm, 120 kV, and 40mAs. CT scans with identical window width (400 HU and window level 1800 HU) were obtained for optimal evaluation of bony structures.

Obtained data were transferred to an Advantage Windows Workstation (General Electric Medical Systems), where planar images were reconstructed. We obtained reformatted sagittal images of 0.3mm slice thickness from these data.

The assessment was made on two monitors (Siemens Simomed HM54) using J.Vision from Tiani (version 3.3.13) viewing software. A precise navigation is possible when using LiveSync. This is a special feature of J.Vision that allows a synchronic demonstration of skull in two different planes. When analysing the pictures sequentially, the slides on the second monitor changes automatically according to movement and position of observer's pointer. We also used a point-to-point-measurement feature with an accuracy of 0.1mm; On the one hand to draw a straight line (see 3.2.), on the other hand to get the distance between two landmarks.

Sagittal plane was selected, because in osteopathic thinking vertical strains of the SBS have a bearing on the rest of the skull. Especially the face is influenced from patterns of the SBS in a typical way.

A superior vertical strain of the SBS means, that sphenoid goes into flexion (up) and occiput goes into extension (down). Maxilla and upper face follow the movement of sphenoid and become external rotated. Mandible goes together with the occiput and reacts to internal rotation. That causes an abnormal occlusion of the teeth (Prognathy) and a typical appearance of the face (Fig.13).



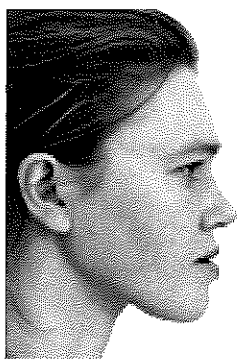


Fig. 13: *Prognathy, superior vertical strain*

With an inferior vertical strain the upper face with maxilla goes into internal rotation while mandible becomes external rotated (Fig.14).

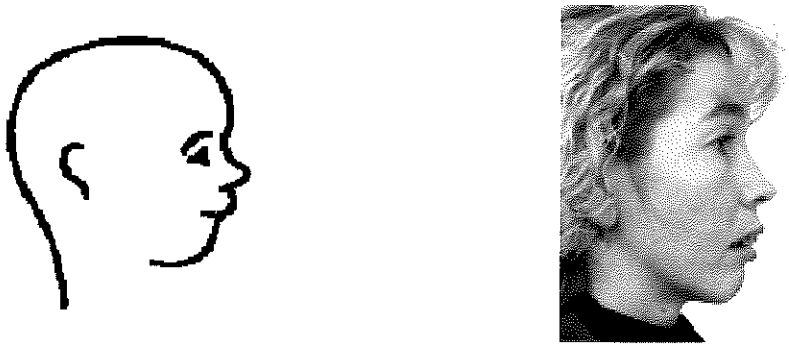


Fig. 14: *Retrognathy, inferior vertical strain*

In a primary selection we tried to find out all cases of interest. We used dichotomy variables. All cases of interest were studied a second time aiming to find out the degree of shifting. Like the osteopathic principle "function governs the structure" (Still, 1902) the areas we want to measure have adapted. That means that there is no geometric structure that can be determined easily. The main problem is to find a landmark for measurement on sphenoid and occiput. In general, this is a common difficulty in Radiology. For this study we decided to work out the degree of shifting on original images only (no zooming or magnifications). Otherwise we would loose resolution and accuracy.

For all cases with minimal (incapable of measurement) changes at SBS we decided to interpret them from a radiological and osteopathic viewpoint. For all cases with irrelevant variances one picture was saved for basic datas.

3.2. Measurements

Before starting evaluation, we tried to find out accuracy of our method. Therefore we tried to find out landmark relocation error (see chapter 3.4.). The way we worked it out was to repeat determination on one sequence. This is a common procedure in Radiology not only for bony structures but also for volumetric analyses and lumen measurements (Tng, 1994 - Hägg, 1998). We repeated determination (for five times) on one significant image for the upper part of SBS as well as for the lower part. To find out whether our measurement is influenced of a wide range of mavericks we assessed median value. To get significant median, we decided to make five measurements. Abbott suggested double determination for assessment. It indicates that the CT technique has acceptable validity and reproducibility in its application to normal and abnormal structures (Abbott, 1990). Therefore, the same radiologist repeated measurement on the same picture for a second time at the following day. All together we got 20 samples from the first radiologist. To find out inter-examiner variability we repeated the same procedure with a second (experienced) radiologist. We also used double determination for measurement at relevant patient. We got 34 samples for upper part and 34 for lower part of SBS.

Afterwards we analysed datasets statistically (40 samples for landmark relocation error, 64 for case of interest). To work out mean value ($\bar{x}$), we used the sum of measurements divided by the number of determinations (arithmetic mean). It is defined by:

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i$$

X_i = result of one measurement

n = number of samples

As we knew the mean value we took the formula below to find out variance (σ^2):

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2$$

Finally standard deviation (σ) was evaluated by means of variance. It is defined as the square root of the variance.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^2}.$$

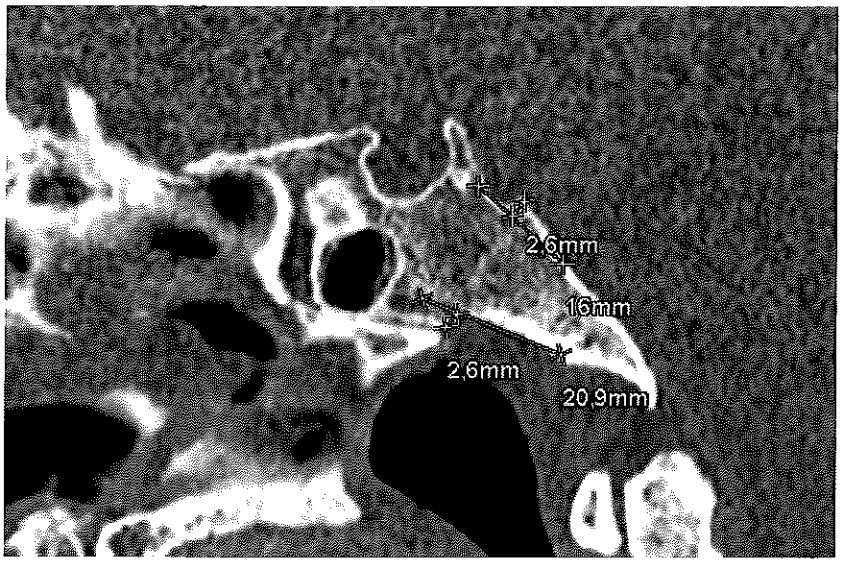
Mean value, median, variance and standard deviation were calculated by using Microsoft Excel software. We defined our landmark relocation error as arithmetic mean of the four measurements.

In a first step we tried to find all cases with relevant alteration at SBS. For a precise navigation we used LiveSync, a special feature of J.Visions viewing software (see 3.1.). When starting the assessment, we first searched the joint-gap of the SBS. If we could not find the connection between the two bones we analysed the characteristics of the top and the bottom of Clivus. If there is a shift, one must find an interruption of consistency on both sides. We assume that if there is a change in position, it needs to be at SBS. This is obvious when the synchondrosis is not closed. But also after the closure, one can expect a shift at the same place. Sutherland describes a histological change of tissue even after an ossification of the SBS (Sutherland 1940).

In a second step we analysed the degree of shifting. Therefore one landmark is posed to the top of basi-sphenoid nearby joint gap. We measured the way to a second landmark which is placed at the top of basi-occiput by use of our viewing software (accuracy of a measuring instrument: 0,1mm). There are two kinds of distance measurement. The first possibility is to use an online illustration of datas when moving the pointer. The second way is to set landmark first and get results by double-clicking afterwards. To get unaltered results we applied the second way of measurement.

The same procedure is used for the bottom of clivus using the lower border of sphenoid respectively the lower part of occiput. The slide-thickness is 0,3mm.

As mentioned above the SBS is not a geometric structure. Therefore we decided to use the integrated distance measurement function to find a landmark (Fig.15). A straight line was placed over the edge of sphenoid and occiput. The first landmark was then positioned exactly at joint gap of the SBS. The direction of measurement was along SBS to the second landmark (below or above).



(Note: Picture is magnified for better illustration)

Fig. 15: *Measurement of shift*

3.4. Errors of measurement

Although CT is relatively accurate, it is liable to produce artefacts, such as streaks or motion artefacts. Another possibility is the so called "Partial Volume Effect". This appears as 'blurring' over sharp edges. It is due to the scanner being unable to differentiate between overlying structures and respective HU's. The processor tries to average out the two densities or structures (Dössel, 2000 - Reiser, 2006).

In areas of research such as morphometrics, it is very important to establish the degree of reliability of methods employed. Errors of measurement can be either systematic or random. Systematic errors arise from limitation in the materials or methods used, leading to consistent over- or underestimation e.g. failure to correct for magnification factors, measuring from copy records where expansion may have occurred, or measurements made by different observers with different concepts of particular landmarks. That is the reason why we used original images only without zooming in.

Random accidental errors may result from variations in positioning of patients, or variations in film density and sharpness in cephalometric studies. Perhaps the greatest source of random error is difficulty in identifying a particular landmark or imprecision in its definition. This problem is known as landmark relocation error. We evaluated this fault of measurement by repeating determinations. To get one numerical data we took mean value of standard deviation of our (four)

measurements. This is one important factor for reproducibility of measurement. Reproducibility refers to the closeness of successive measurements of the same object. It varies depending on quality of records, the conditions under which they are measured, and the care and skill of the measurer. There are studies for the problem of reproducibility for numerous parts of the body, but none for base of the skull. They include the point-setting as well as inter-rater variability (Dahlstrom, 1996, Kobayashi, 2004, Zannoni, 1997).

Another problem is the great diversity of nature with its great ability to adaptation. It seems to be obvious, that we will find not only one pattern of compensation. Most of the time there are two or more adjustments of structure. This is important to keep in mind when thinking about radiological or osteopathic interpretation of changes at SBS.

4. Results

4.1 Landmark relocation error

Before starting the analyses we determined landmark relocation error by testing our method at one significant image at the upper and the lower part of the SBS.
Table 1 and 2 show the results of measurement (x) by the first tester at the upper part.

1st tester: 1st measurement	x	x-xD	(x-xD)^2
1	2,4	0,16	0,0256
2	2,1	-0,14	0,0196
3	2,3	0,06	0,0036
4	2,0	-0,24	0,0576
5	2,4	0,16	0,0256
Sum	11,2		0,132

MV (xD):	2,2400
Variance	0,0264
Standard deviation.	**0,16**
Median	2,3

Note: MV....mean value

Table 1: *First tester, first measurement, upper part*

1st tester: 2nd measurement	x	x-xD	(x-xD)2
1	1,8	-0,12	0,0144
2	2,0	0,08	0,0064
3	1,7	-0,22	0,0484
4	1,9	-0,02	0,0004
5	2,2	0,28	0,0784
Sum	9,6		0,148

MV (xD):	1,9200
Variance	0,0296
Standard deviation	**0,17**
Median	1,9

Table 2: *First tester, second measurement, upper part*

Mean value of shift determined by the first tester for upper part of SBS is 2.1mm (SD: 0.17mm, range -0.24mm to 0.28mm)

Table 3 and 4 show the results of a second tester at the same area:

2nd tester: 1st measurement	x	x-xD	(x-xD)2
1	1,9	-0,14	0,0196
2	2,0	-0,04	0,0016
3	2,1	0,06	0,0036
4	1,9	-0,14	0,0196
5	2,3	0,26	0,0676
Sum	10,2		0,112

MV(xD)	2,04
Variance	0,0224
Standard deviation	**0,15**
Median	2,0

Table 3: *Second tester, first measurement, upper part*

2nd tester: 2nd measurement	x	x-xD	(x-xD)2
1	1,6	-0,30	0,09
2	2,1	0,20	0,04
3	2,0	0,10	0,01
4	1,8	-0,10	0,01
5	2,0	0,10	0,01
Sum	9,5		0,16

MV(xD)	1,90
Variance	0,03
Standard deviation	**0,18**
Median	2,0

Table 4: *Second tester, second measurement, upper part*

Mean value of shift determined by the second tester for upper part of SBS is 2.0mm (SD: 0.17mm, range -0.30mm to 0.26mm)
Landmark relocation error is defined by the mean value of standard deviation of the four measurements. It is 0.2mm for the upper part.
There are only minimal differences between the two testers (0.1mm).

We used the same procedure for the lower part of SBS. Mean value of the shift determined by the first tester is 2.3mm (SD: 0.18mm, range -0.28mm to 0.30mm). Second tester assessed a shift of 2.4mm (SD: 0.15mm, range -0.16 to 0.26). The inter-examiner variance is minimal (0.1mm).
Table 5-8 show the results of measurement.

1st tester: 1st measurement	x	x-xD	(x-xD)2
1	2,6	0,22	0,0484
2	2,3	-0,08	0,0064
3	2,5	0,12	0,0144
4	2,1	-0,28	0,0784
5	2,4	0,02	0,0004
Sum	11,9		0,1480
MV (xD):	2,38		
Variance:	0,0296		
Standard deviation	**0,17**		
Median	2,40		

Table 5: *First tester, first measurement, lower part*

1st tester: 2nd measurement	x	x-xD	(x-xD)2
1	2,5	0,3	0,09
2	2,1	-0,1	0,01
3	2,0	-0,2	0,04
4	2,1	-0,1	0,01
5	2,3	0,1	0,01
Sum	11,0		0,16
MV (xD):	2,2		
Variance:	0,032		
Standard deviation	**0,18**		
Median	2,10		

Table 6: *First tester, second measurement, lower part*

2nd tester: 1st measurement	x	x-xD	(x-xD)2
1	2,3	-0,06	0,0036
2	2,5	0,14	0,0196
3	2,2	-0,16	0,0256
4	2,6	0,24	0,0576
5	2,2	-0,16	0,0256
Sum	11,8		0,1064
MV (xD):	2,36		
Variance:	0,02128		
Standard deviation	**0,15**		
Median	2,30		

Table 7: *Second tester, first measurement, lower part*

2nd tester: 2nd measurement	x	x-xD	(x-xD)2
1	2,2	-0,14	0,0196
2	2,6	0,26	0,0676
3	2,2	-0,14	0,0196
4	2,4	0,06	0,0036
5	2,3	-0,04	0,0016
Sum	11,7		0,1104
MV (xD):	2,34		
Variance:	0,022		
Standard deviation	**0,15**		
Median	2,3		

Table 8: *Second tester, second measurement, lower part*

Landmark relocation error for the lower part is the same as for the upper part (0.2mm). Because both parts have changed position, it indicates to be a real shift at SBS. If you compare mean value to median, you can find high accordance in all cases. That means that there is no wide range of mavericks (statistical dispersion from -0.28 to 0,30mm). All together we got homogeneous results for the upper part of SBS as well as for the lower part.

4.2. Measurement of first patient

In a first selection we assessed 5 cases (3.6%) with at least minimal changes at SBS. We analysed this cases a second time, and could figure out one patient with considerable alteration. For accurate measurement, we used double determination for every single slide in sagittal plane at area of interest. Datas are summarized in Table 9 for upper part of SBS.

sequence	1st m.	2nd m.	xDm	difference	xDm-xD	xDm-xD^2
1	0,8	0,9	0,85	-0,1	-0,8059	0,6494
2	1,5	1,6	1,55	-0,1	-0,1059	0,0112
3	1,7	1,4	1,55	0,30	-0,1059	0,0112
4	1,7	1,5	1,6	0,20	-0,0559	0,0031
5	1,5	1,8	1,65	-0,30	-0,0059	0,0000
6	1,6	1,8	1,7	-0,20	0,0441	0,0019
7	2,2	2,0	2,1	0,20	0,4441	0,1972
8	2,2	2,0	2,1	0,20	0,4441	0,1972
9	2,0	2,1	2,05	-0,10	0,3941	0,1553
10	2,4	2,7	2,55	-0,30	0,8941	0,7994
11	2,4	2,6	2,5	-0,20	0,8441	0,7125
12	1,8	1,8	1,8	0,00	0,1441	0,0208
13	1,8	1,4	1,6	0,40	-0,0559	0,0031
14	1,7	1,3	1,5	0,40	-0,1559	0,0243

15	1,4	1,2	1,3	0,20	-0,3559	0,1267
16	1,1	0,9	1	0,20	-0,6559	0,4302
17	0,8	0,7	0,75	0,10	-0,9059	0,8206

Sum	28,6	27,7	28,15	0,90		4,1644
MV (xD):	1,6824	1,6294	1,6559	0,05		
Median	1,7	1,6	1,6	0,1		
Variance:	0,2203	0,2950	0,2450			
SD	**0,47**	**0,54**	**0,49**			

Note: xDm....mean value of first and second measurement

Table 9: *Datas of measurement at upper part of SBS*

It is remarkable that datas have sinuous characteristics at both measurements. That means a different extent of shift when running through sequences. For better illustration see table 10.

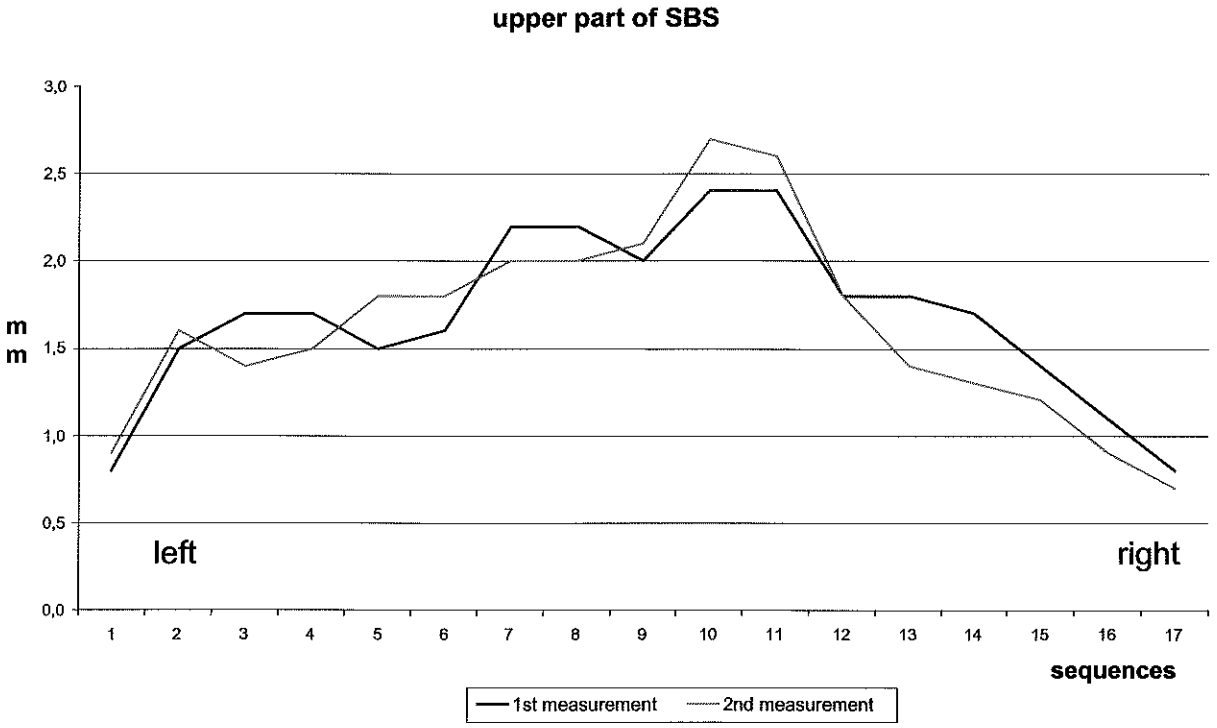


Table 10: *Characteristics of data - upper part*

The mean value of shift is 1.7 mm (SD: 0.49mm, range -0.30 to 0.40). There are only minimal differences between the two measurements as concerns mean value and median (0.1mm). That indicates a low range of mavericks.

Table 11 shows the results of measurement for the lower part of SBS. Similar to the upper part dataset have sinuous characteristics. See table 12 for details.

sequence	1st m.	2nd m.	xDm	difference (d)	xDm-xD	xDm-xD^2
1	1,2	1,3	1,25	-0,1	-0,9559	0,9137
2	2,5	2,3	2,40	0,2	0,1941	0,0377
3	2,3	2,5	2,40	-0,2	0,1941	0,0377
4	2,6	2,9	2,75	-0,3	0,5441	0,2961
5	2,6	3,1	2,85	-0,5	0,6441	0,4149
6	2,2	2,5	2,35	-0,3	0,1441	0,0208
7	2,1	1,9	2,00	0,2	-0,2059	0,0424
8	2,4	2,1	2,25	0,3	0,0441	0,0019
9	1,9	2,1	2,00	-0,2	-0,2059	0,0424
10	2,3	2,5	2,40	-0,2	0,1941	0,0377
11	2,6	2,6	2,60	0,0	0,3941	0,1553
12	2,3	2,4	2,35	-0,1	0,1441	0,0208
13	3,0	2,7	2,85	0,3	0,6441	0,4149
14	2,2	2,3	2,25	-0,1	0,0441	0,0019
15	1,9	1,8	1,85	0,1	-0,3559	0,1267
16	1,6	1,5	1,55	0,1	-0,6559	0,4302
17	1,5	1,3	1,40	0,2	-0,8059	0,6494
Sum	37,2	37,8	37,5	-0,60		3,6444
MV (xD):	2,1882	2,2235	2,2059	-0,035		
Median	2,3	2,3	2,4	-0,1		
Variance:	0,1952	0,2594	0,2144			
SD	**0,44**	**0,51**	**0,46**			

Table 11: *Datas of measurement at lower part of SBS*

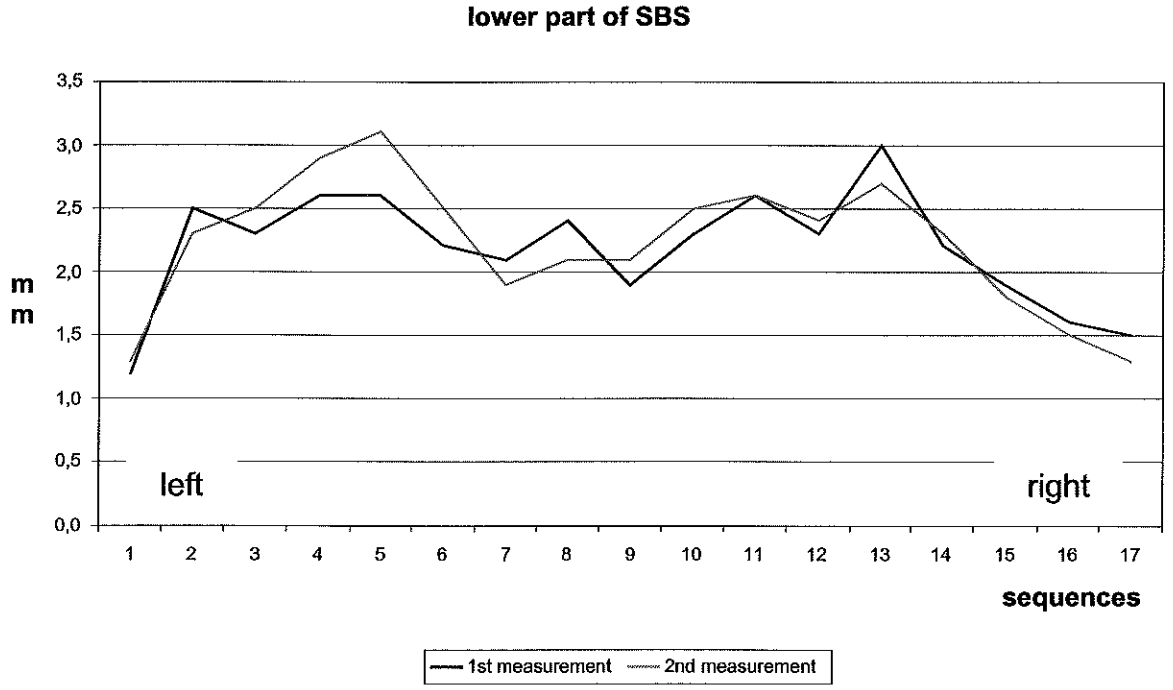


Table 12: *Characteristics of data - lower part*

Mean value of shift at the bottom is 2.2 mm (SD: 0.46mm, range -0.50 to 0.30). There is only minimal difference between the two measurements as concerns mean value and median (0.2mm). That indicates a low range of mavericks.
Table 13 shows mean variation of upper and lower part of SBS.

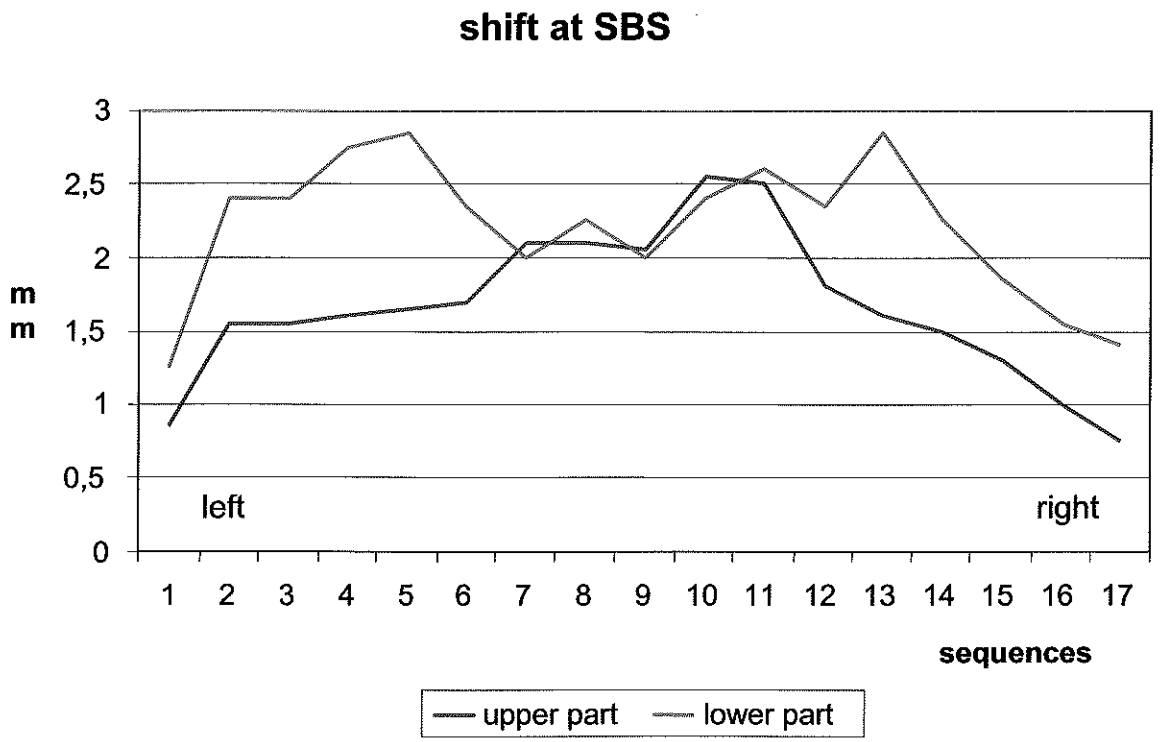


Table 13: *Shift at SBS*

Shift of the lower part is greater than at upper part in general. It is remarkable, that there is a variation mainly at left and right side. It seems to be equal in between. From an osteopathic viewpoint, this outcome can be interpreted as inferior vertical strain. Fig. 16 shows a mid-sagittal reformatted image of this patient.

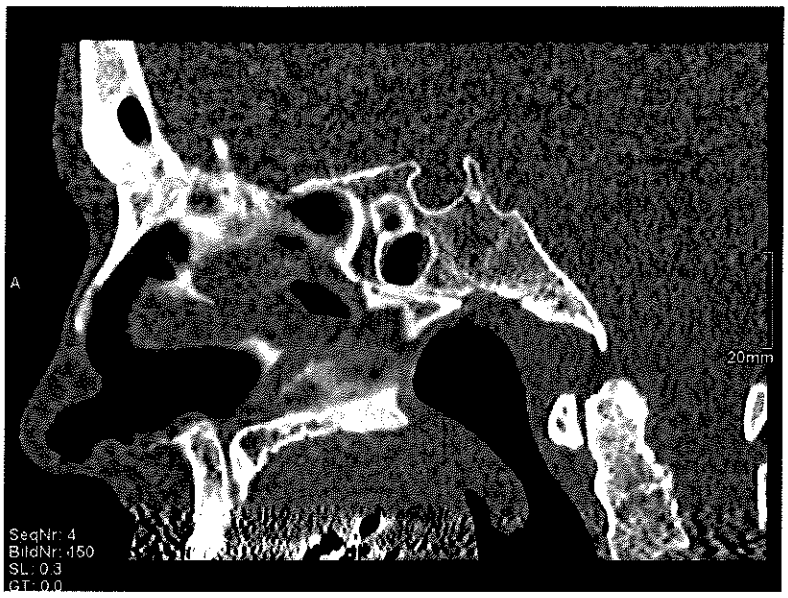


Fig. 16: *Inferior strain*

4.3. Assessment of patient 2-5

At 4 patients the degree of alteration was minimal, and not at the whole width of Clivus. Therefore we decided not to make measurements from every single slide, but to analyse it dynamically by scrolling through sequences. Then the result is a radiological interpretation of pictures for every single patient. Radiologists were allocated to evaluate Clivus with SBS only.

Radiological findings with one illustration are summarised at Fig. 17-20.

4.3.1. Patient 2

(E.S, female, 30 years):

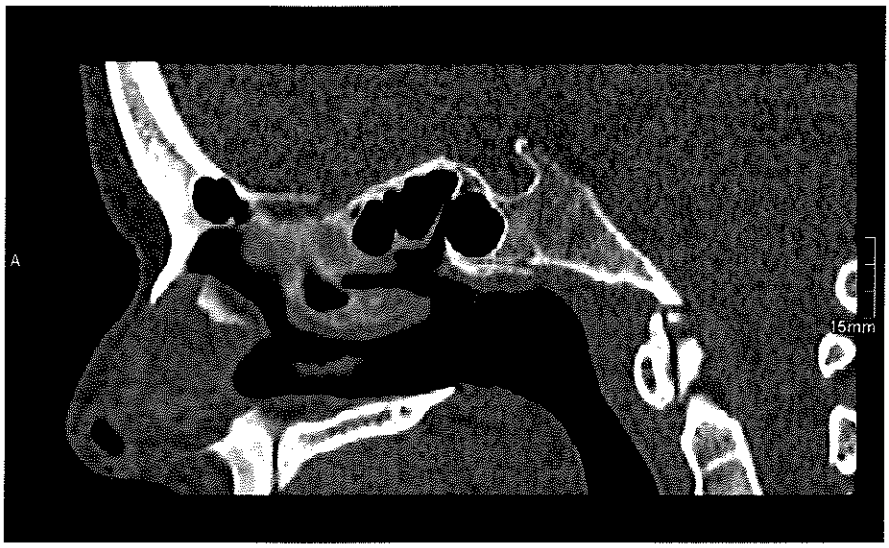


Fig. 17: *Minimal variation of SBS – Case1*

Radiological Statement:

SBS can be determined at all sequences in area of interest and it is closed. Cortical bone has constant margin and thickness. In midsagittal plane cranial-caudal diameter is about 15.8mm, basi-occiput has a length of 28.5mm at the upper side, basi-sphenoid about 17.7 mm to posterior clinoid process. Over a distance of about 2.4mm there is a sinuous alteration of the upper border of Clivus with an apex of 0,6mm at the left third of basi-occiput. It is unsafe to verify this variation as a changing in position. For it is a short distance it can also be considered as an exostosis or an osteophyte.

From an osteopathic viewpoint you can think of torsion or rather sidebending-rotation at SBS although it is a very small part. Otherwise it could be interpreted as an intra-osseous strain (e.g. compression) which has changed the structure.

4.3.2. Patient 3

(W.G, female, 56 years):

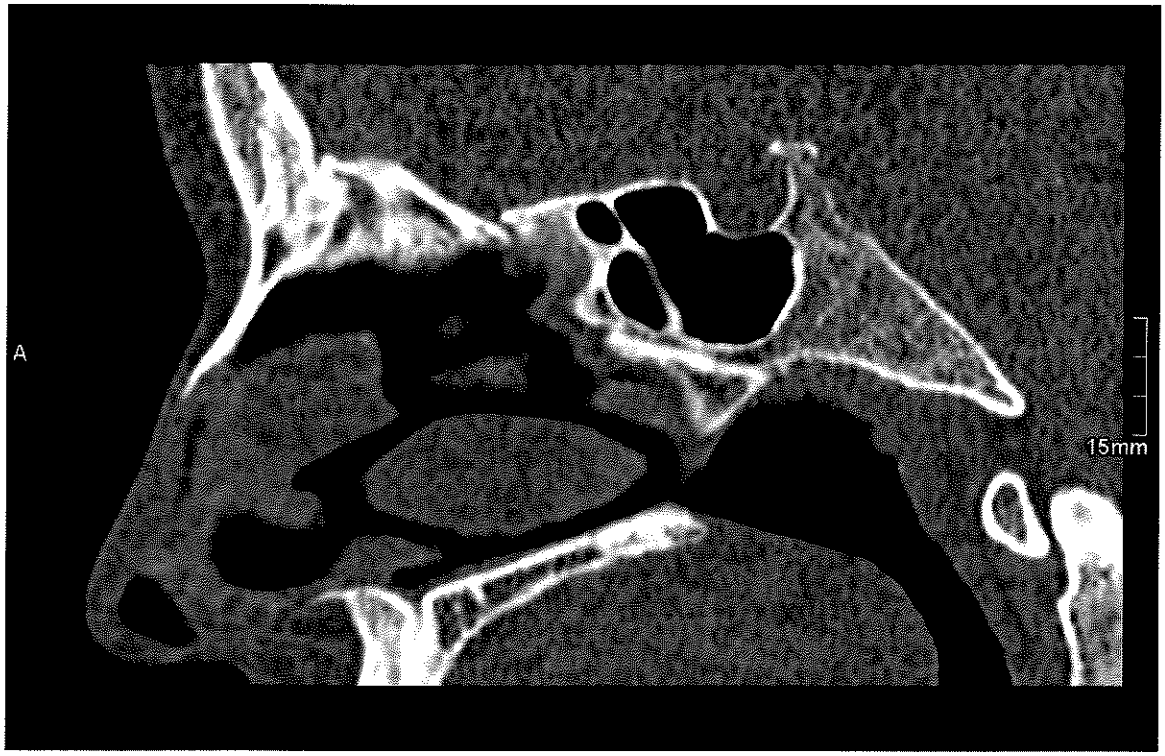


Fig. 18: *Minimal variation of SBS – Case 2*

Radiological Statement:
SBS can hardly be determined at most of the images. The suture is closed. Cortical bone has inconstant margin and thickness especially at area of basi-sphenoid. In midsagittal plane cranial-caudal diameter is about 14,7mm, basi-occiput has a length of 26.5mm at the upper side, basi-sphenoid about 15.4 mm to posterior clinoid process. Over a distance of about 3 mm there is an alteration of upper and lower border of Clivus with a maximum of about 0,5mm. It is possible to verify this variation as a shift of position for this small part of SBS. Because it is a short distance it can also be considered as an exostosis (tuberculum?).

From an osteopathic viewpoint you can also think of torsion or sidebending-rotation at SBS. Otherwise it could be interpreted as an intra-osseous strain which has changed the structure.

4.3.3. Patient 4

(T.G., male, 43 years):

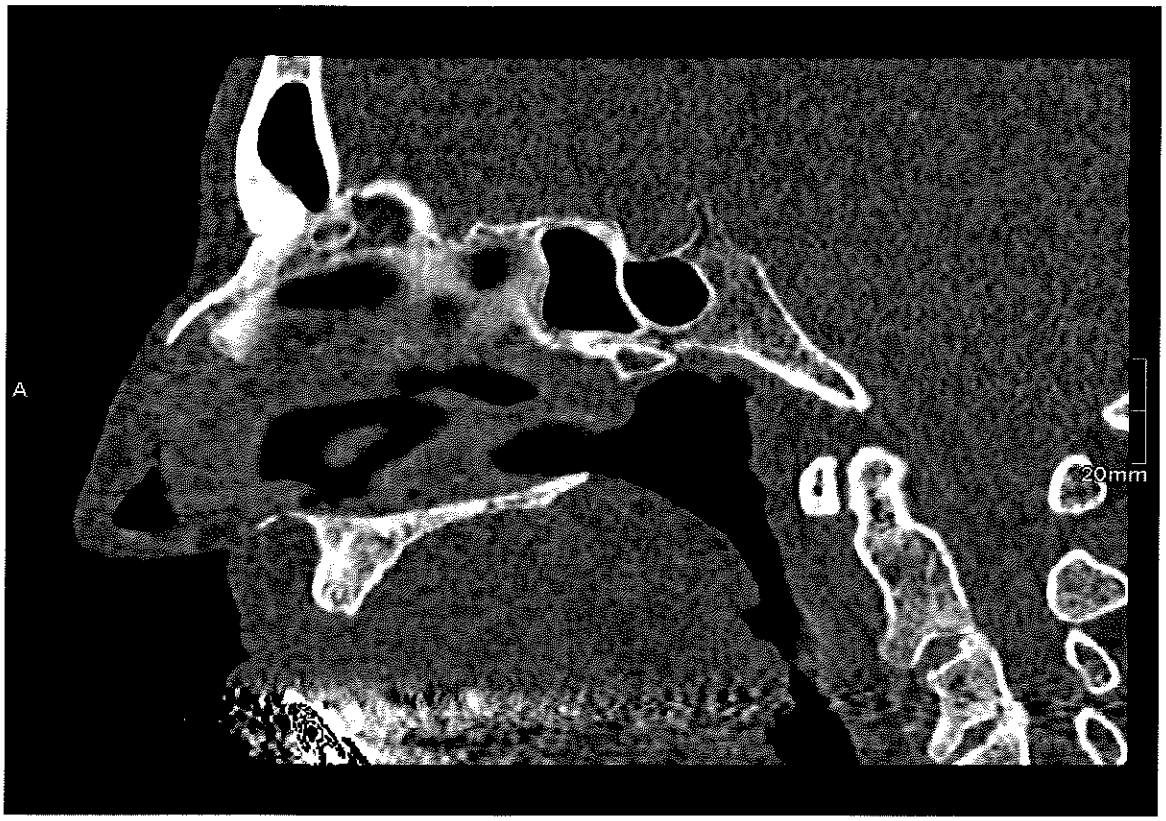


Fig. 19: *Minimal variation of SBS – Case 3*

Radiological Statement:
SBS can be determined at all sequences in area of interest and it is closed. Cortical bone has constant margin and thickness. In midsagittal plane cranial-caudal diameter is about 15.5mm, basi-occiput has a length of 26.5mm at the upper side, basi-sphenoid about 13.6 mm to posterior clinoid process. Over a distance of about 2.1mm there is a sinuous alteration at SBS with an apex of 1.1 mm at midsagittal basi-occiput. It seems to be rather an osseous variation than a changing in position because of short distance and midsagittal position.

From an osteopathic viewpoint you can think of an intra-osseous strain (e.g. compression) which has changed the structure in a formidable way.

4.3.4. Patient 5

(H.F., male, 71 years):

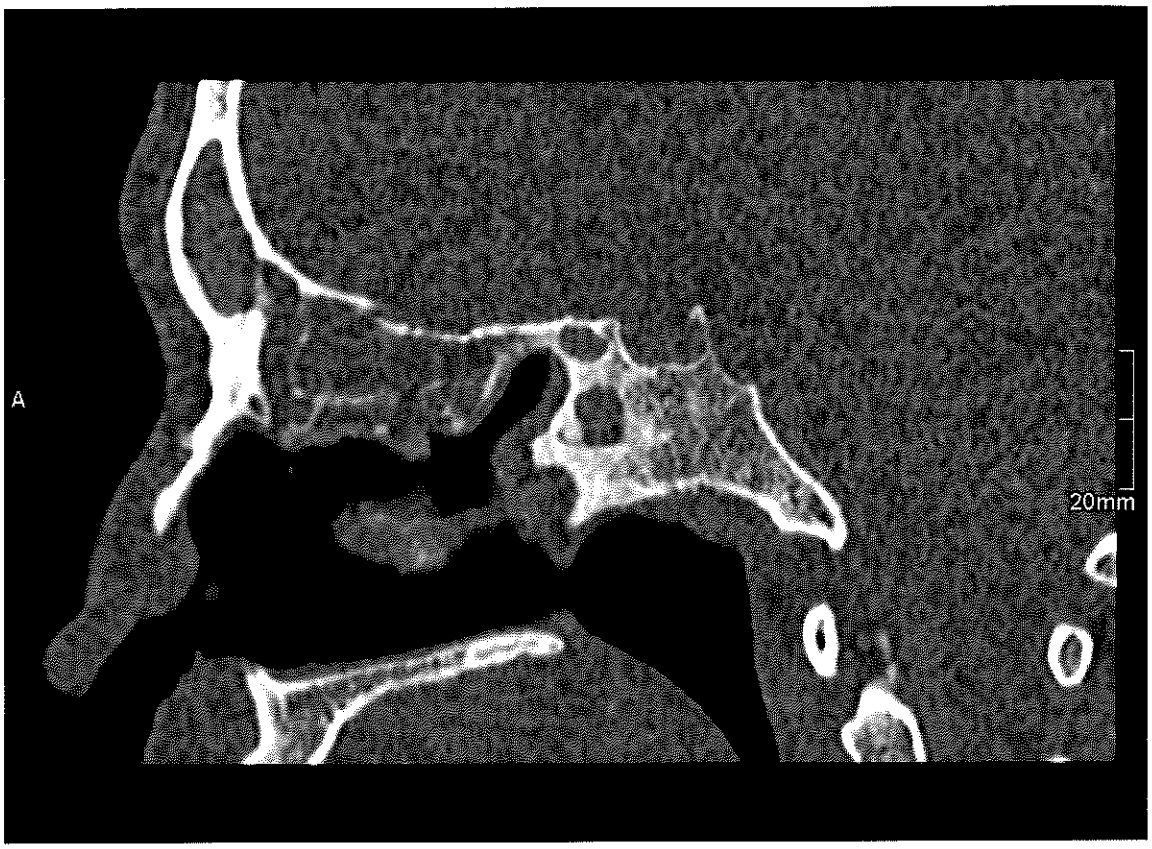


Fig. 20: *Minimal shift of SBS – Case 4*

Radiological Statement:

SBS can be determined at all sequences in area of interest and it is closed. In midsagittal plane cranial-caudal diameter is about 16.2mm, basi-occiput has a length of 34.2mm at the upper side, basi-sphenoid about 15.5 mm to posterior clinoid process. Cortical bone has constant margin and thickness. Over a distance of about 4 mm there is a sinuous alteration at SBS with an apex of 1.6 mm at two sequences, and about 0.8mm at the rest. One can verify this variation as a shift of position of SBS.

From an osteopathic viewpoint you can think of a superior vertical strain, because also the lower part of SBS has shifted. There also seem to be intra-osseous alteration.

All together we found (as expected) a high variation of shape and size of SBS respectively sphenoid and occiput. It seems to be obvious, that in most cases there is not only one pattern but a combination of two or more compensations with different degrees of alteration.

But also face structures like nasal septum or the nose itself showed partly strong asymmetry.

5. Discussion

Basic research is the most important part for a legitimisation of Osteopathy in medicine. Compared to other disciplines, Osteopathy is an old concept. Nevertheless up to our days there are lots of references to A.T.Still and his successors. Therefore it is a challenge to reassess this old knowledge with modern methods and instruments.

Technological progress enables more accurate and complex measurements. We know that results of scientific research depend on numerous influencing factors. In this study I presume that these factors are low. There is high knowledge and good acceptance of computed tomography. Pictures do have good quality (digital imaging, more and more in 3D) and they are available at all times for different persons. Experienced radiologists are able to distinguish between artefacts and true alterations of structures. But the accuracy of measurement and its (clinical) interpretation depends basically from experience, care and skill of measurer. Moreover, it is important to know that this study can give an advice only about position and the morphology of the bones. There is no information about dynamic procedures like movement or pathology of SBS. It is also remarkable that we used CT-scans which were primary realised for clinical use. Only sagittal plane was reconstructed for this study. All together we took up about 5 GB (!) of disk space for storage of additional datasets. Nevertheless, to get more accurate results it seems to be necessary to work out specific images for area of interest. It would be interesting to work out sections in plane of SBS. With these images a more accurate assessment of clivus can be realised. We also tried to reconstruct 3D images from basic data via Vitrea viewing software. Unfortunately, there was less accuracy for realistic measurement. Despite all, technical development goes on, and in near future it will be possible to create detailed 3D-images from SBS.

There is less knowledge about the base of the skull itself. Regarding the histological configuration, it seems to be obvious that the position of patient during examination has no influence on the position of the SBS in a relevant way. It is different for other structures like fluids or soft tissues.

As concerns the position of SBS there is a strong advice for a shift at least in one case as described in chapter 4. The reason for this variance may be a trauma in the time before closure of SBS. We had the possibility to meet this patient, when he came to hospital half a year after CT-scanning. In fact he reported a bicycle-accident

with the age of 9 years (without helmet). As far as he can remember, there were no serious injuries. However, he can remember this situation and that may be an indicator for an ongoing procedure.

It is difficult to predict frequency of SBS shifts for a great population. You need a higher number of cases to give valid information particularly with regard to a rare occurrence of severe accidents. But if you think of forces during birth-giving or traumas with head injuries, there must be an adaptation of structures. Consequentially, it seems realistic that there can be a shift when SBS is not ossified yet. Or we can find a fracture after closure of the synchondrosis.

We know that our body always tries to redress balance of all structures. Therefore it is plausible, that in CT scanning we cannot always find disorder not even to a little extent.

If we look at the basics of cranial concept, we know that there is bad (scientific) evidence of cranial mobility or the existence of the PRM (Green, 1999 - Sommerfeld, 2006).

Nevertheless, our study shows that shifts of the SBS do exist. To a great part they are minimal and it needs high quality scans with specific investigations at area of interest. We only assessed position of SBS. For it was the first research at SBS in this manner, we cannot compare our findings with other studies. There is no evidence about motion, clinical aspects or treatment in this master thesis.

Therefore it would be interesting to go the other way round. In a mechanical, osteopathic view it may be of interest to examine patients with more or less severe SBS pattern or other problems of the head. Osteopathic findings can be supported by using CT-scan. On the other hand it is clear, that a scan is a snap-shot of reality. It cannot compensate for palpation of dynamic processes by an osteopath.

Moreover, osteopaths have a precise knowledge and unique understanding of the bones of the skull. Therefore it could be an enrichment of work using imaging methods particularly when thinking of the enormous variability of anatomical structures.

In our days it is not difficult to order a CT examination for patients. If we think of the indications for this exploration we will find a large number of patients with a referral to a radiological examination from their medical doctor. For numerous diseases it is state of the art to make a CT-Scan. Based on this study, it is realistic to get more information about SBS, especially in consideration of clinical aspects.

It is particularly noticeable that our results are excellent compared to standard deviation of skull measurement in other studies (Crawford, 1990 – Oyar, 1996 – Yonetsu, 1999 – Kane, 2000). It cannot be compared to other regions of the body or 3D-analyses.

We could not find any persistence of SBS. Sutherland reported an age of 25 for closure (Sutherland, 1939). Our youngest patient was 20 and we analysed 5 persons with an age to 25. This supports the findings of Powell from 1963 as concerns the closure of SBS with a maximum age of 16 (Powell, 1963).

Yonetsu describes an expansion and reduction in aeration of the sphenoid sinus depending from age (Yonetsu, 1999). We can confirm his findings. It was interesting to see the great inconsistency of air sinus.

It is astonishing that mean age of your patients is 48.53 at women and 48.41 at men. We do not have an explication for this circumstance. Maybe it is a statistical coincidence.

There are some limiting factors for this study. First, the number of samples (n=138) is to low to predict a valid number of shifts or strains at SBS for a greater population. Second, it is possible to find more positive cases because we used patients only for the study. In osteopathic thinking you can argue, that changes at SBS may cause a higher number of ear, nose and throat problems. In turn, this fact will lead to exceeding cases of SBS variations. But for ethic causes (radiation exposure!) it is not possible to scan healthy people for control group to a greater extent.

As mentioned above we used images which were made for clinical purpose. For scientific research it is necessary to concentrate on the structure and area of interest. Then it is possible to draw out more precise viewings of Clivus and SBS.

I consider 5 cases out of 138 (3.6 %) for a remarkable number of alterations even when the degree is minimal. Nonetheless patients with a shift of 2 mm or more seem to be rare.

Nevertheless we can corroborate our hypothesis. Perhaps it can clear the way for further investigations especially to clinical (osteopathic) claims.

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Fig. 10,11: Liem Torsten, Kraniosakrale Osteopathie, Hippokrates, 3.Auflage 2001, 498

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9. Abstract

The purpose of this master thesis is to find out shifts at the SBS which can be demonstrated by means of computed tomography in sagittal plane.
We retrospectively reviewed paranasal sinuses CT images from 76 male and 62 female patients (n=138) aged 20 to 86 years.

Before starting the analyses, we assessed accuracy of our measurement method by evaluating landmark relocation error (LRE). We got excellent results (LRE: 0.2mm, range: -0.28mm to 0.60mm).

In a primary selection we tried to find out all cases of interest. There were 4 cases (2m/2f) with minimal changes. We analysed them from a radiological and osteopathic viewpoint. Because variations were minimal and only at a small part of SBS, they can be interpreted radiological as intra-osseous lesions with alteration of structure. From an osteopathic viewpoint, it also can be a minimal torsion or side bending/rotation lesion.
At one male person we found greater alterations with relevant variation of the SBS. We tried to determine the degree of shifting for this particular case.
Shift was assessed at upper and lower part of SBS by using double determination for valid results. We found a sinuous alteration of 1.7mm (SD: 0.49mm, range -0.30 to 0.40) for the upper part and 2.2mm (SD: 0.46mm, range -0.50 to 0.30) for the lower part. From an osteopathic viewpoint it can be interpreted as an inferior vertical strain.

Our study shows that shifts of the SBS do exist. To a great part they are minimal and it needs high quality scans with specific investigations at area of interest. Considerable shifts seem to be rare. We only assessed position of SBS. There is no evidence about motion or clinical aspects in this master thesis.
Nevertheless we can corroborate our hypothesis. Perhaps it can clear the way for further investigations especially to clinical (osteopathic) claims.

Key words: *skull base, SBS, shift, computed tomography, landmark relocation error*

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Finally, I would like to express my thanks to **WSO** for teaching me osteopathy for the last 6 years.

11. Basic datas of the study

11.1. Basic Data men

Name	Geburtsdatum	Alter	Ja	Nein	Kommentar
A. Ch.	3.7.1969	38		X	
A. R.	27.5.1962	45		X	
A K.	23.2.1937	70		X	ev offener Gelenkspalt?
A. H.	1.1.1964	43		X	
B. M.	21.8.1977	30		X	
B. Ch.	10.4.1962	45		X	minimal
B. L.	13.10.1941	66		X	
B. H.	29.12.1971	36		X	Ev 155
B. G.	3.7.1962	45		X	
C. A.	9.7.1968	39		X	
D. O.	4.8.1943	64		X	Großer Sinus
D.G.	23.3.1964	43		X	
D. T.	13.8.1970	37		X	
E. F.	25.5.1981	26		X	
F. R.	1.3.1953	54		X	
F. P.	16.1.1941	66		X	
F. J.	27.5.1967	40		X	
G. M.	19.9.1937	70		X	
H. H.	21.1.1952	55		X	
H. F.	23.4.1936	71	x		Bildnr. 151-161
H. P.	12.11.1966	41		X	
H. E.	28.7.1953	54		X	
J. S.	8.12.1960	47		X	
J. M.	26.4.1952	55		X	
K. G.	18.4.1972	35		X	
K. E.	17.6.1956	51		X	
K. D.	21.4.1960	47		X	
K. M.	1.12.1942	65		X	
K.M.	14.1.1978	29		X	
K. M.	25.5.1952	55		X	
K.L.	28.8.1941	66		X	
K. H.	9.1.1958	49		x	
K.J.	12.7.1954	53		X	
K.M.	15.6.1969	38		X	
K.K.	15.3.1945	62		X	
K. K.	12.7.1940	67		X	
K. A..	28.2.1940	67		X	

L. H.	25.8.1940	67		X	Ev. Bildmitte 5160172
L.J.	3.1.1961	46		X	Oberkante?
L. G.	30.10.1952	55		X	
L.T.	3.1.1979	28		X	
L.K. F.	15.7.1956	51		X	
L. S.	23.11.1971	36		X	
M. K.	1.2.1927	80		X	
M. G.	9.5.1960	47		X	
M. M.	26.8.1950	57		X	Gelenkspalt deutlich?
M. A.	21.12.1974	33		X	
M. R. S.	16.11,1930	77		X	
N. R.	10.11.1946	61		X	Großer Sinus
N. K.	26.2.1945	62		X	
P. A.	19.6.1936	71		X	
P. F.	22.12.1955	52		X	
P. J.	23.8.1960	47		X	
P. H.	8.4.1957	50		X	
P. M.	2.8.1973	34		X	
R. G.	6.12.1977	30		X	
R. C.	24.1.1970	37		X	Offene SSB Bildnr.144?
R. S.	24.9.1960	47		X	
R. M.	9.4.1975	32		X	
R. C.	28.7.1976	31	x		5135202 Bildnr. 151
S.A.	14.12.1955	52		X	intraössär
S. F.	8.1.1972	35		X	
S.M.	31.3.1975	32		X	
S. K.	5.3.1957	50		X	
S.H.	7.11.1974	33		X	
S.K.	18.09 1945	62		X	
S.G.	17.4.1956	51		X	minimal
T.R.	3.1.1987	20		X	
T.G.	2.11.1964	43	x		Rotation Bildnr. 153
T.G.	31.05.1946	61		X	
T.N.	5.10.1968	39		X	
T.M.	27.10.1953	54		X	
Ü. C.	12.12.1970	37		X	
W. A.	18.9.1938	69		X	
W. A.	13.11.1961	46		X	
	Mittelwert: 48,41				

11.2. Basic Data women

Name	Geburtsdatum	Alter	ja	nein	Kommentar
A. F.	25.5.1932	75		X	
A. S.	7.5.1982	25		X	Großer Sinus
B.-S. G.	24.3.1963	44		X	
B. V.	25.2.1986	21		X	
B. S.	18.3.1975	32		X	
B. R.	30.8.1968	39		X	
B.J.	17.5.1942	65		X	
D.H.	24.11.1942	65		X	
D. R.	6.11.1951	56		X	
D. I.	14.9.1948	59		X	
D.S.	10.8.1978	29		X	minimal
D. A.	17.5.1960	47		X	
E. M.	6.1.1970	37		X	
E. E.	11.3.1985	22		X	
E. S.	5.6.1970	37	x		Nicht durchgehend 130
E. S.	15.10.1977	30		X	
F. S.	25.7.1962	45		X	Oberkante verändert
F. C.	23.1.1953	54		X	
F. E.	2.11.1962	45		X	
F.A.	11.8.1981	26		X	
G. A.	1.12.1960	47		X	
G. M.	11.6.1946	51		X	minimal
H. G.	2.4.1921	86		X	
H. N.	10.9.1981	26		X	Großer Sinus Bildnr.146
H. R.	20.4.1973	34		X	
H. I.	5.1.1973	34		X	
H. M.	23.6.1947	60		X	
H.-P. M.	5.12.1938	69		X	
J. J.	14.9.1980	27		X	
K. A.	27.9.1958	49		X	
K. T.	11.6.1949	58		X	minimal
K. C.	28.3.1977	30		X	Unterkante verändert
K. R.	20.4.1958	49		X	Großer Sinus
K. M.	7.1.1964	43		X	
K. A.	21.2.1954	53		X	Oberkante verändert
K.M.	22.7.1949	58		X	
L. M.	20.7.1932	75		X	
M.K.	25.6.1956	51		X	
M. N.	5.5.1972	35		X	Offene SSB?
N. H.	9.2.1948	59		X	

P. E.	6.5.1940	67		X	
P. E.	8.4.1942	65		X	
P.A.	23.5.1933	74		X	
P. B.	29.10.1959	48		X	
P.G.	19.4.1983	24		X	Offene SSB?
P. D.	27.5.1956	51		X	
P. B.	9.8.1972	35		X	
R. W.	1.10.1948	59		X	SBR (149)
R. M.	15.3.1942	65		X	Minimal Oberkante
R.D.	22.8.1971	36		X	
R.L.	17.8.1952	55		X	Großer Sinus
S. N.	27.8.1950	57		X	
S. J.	24.7.1939	68		X	Großer Sinus
T. E.	3.6.1966	41		X	
W. A.-M.	13.7.1959	48		X	Bildnr.145 Sinus!
W. G.	26.9.1951	56	x		146-156
W. M.	7.6.1954	53		X	
W. H.	19.5.1963	44		X	Bildnr.137/132
W.C.	14.4.1946	61		X	
W. C.	17.3.1960	47		X	
W. I.	11.7.1942	65		X	
W. E.	7.2.1929	78		X	
Z. E.	21.7.1945	62		X	
	Mittelwert: 48,53				