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A magnetic resonance imaging studyof the temporomandibular joint and the disc–condyle relationship after functional–orthopaedic treatment

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Abstract: *Causative correction of skeletal malocclusions is achieved through bite–jumping by various means. Numerous animal experiments yielded evidence of rebuilt temporomandibular structures after mandibular protrusion. However, the mode and extent of structural and/or topographic changes of the disco-condylar relation after functional orthopaedic treatment is still an issue at stake. A problem exists in defining the physiologic (centric) position of the condyles and the proper disco-condylar relation which is tentatively determined by various methods particularly in MRI studies. Despite the high resolution provided, the results have to be interpreted with caution, as osseous resorption and apposition can not be assessed by visual evidence. In this article a prospective study is presented which proves the effectiveness of the "Wuerzburg concept", i.e. bionator plus extraoral traction and up-and-down elastics, and its impact on the temporomandibular joint. The underlying reactions are studied by means of MR images obtained from sucessfully treated patients.*

Keywords: *Disc displacement, internal derangement, posterior disc displacement, temporomandibular disorders*

I. Introduction

Skeletal discrepancies between the maxilla and the mandible in the sagittal, transversal and vertical direction pose an everyday challenge to the orthodontist. While slight deviations are accessible to dento–alveolar measures at any age, the question remains if and how severe sagittal anomalies such as Angle Class II malocclusions can be treated successfully in adolescent patients, that is avoiding the need for orthognathic surgery at older age.

Among the various modalities suggested for treatment of Class II malocclusions (Armstrong 1971, Gianelly et al. 1983, 1991, McNamara, 1966, Petrovic 1973, Reuther, 1988, Stutzmann et al. 1987, Teuscher 1978, Witt 1973, 1988), the functional–orthopaedic treatment using bimaxillary appliances during growth is in the focus of the considerations to follow.

Its rationale is the assumption that functional muscular stimuli are transmitted by the appliance to the periodontal structures, but also exert an influence on the TMJ region where remodelling processes in the glenoid fossa and the condyle are triggered (Häupl, Psansky, 1939). The controversy with the American doctrine of the 70's which regarded mandibular growth as genetically determined and, hence, not accessible to therapy (Ricketts 1952, Armstrong 1971, Coben 1971,) gave new impetus to study the mode of action of functional–orthopaedic devices. An increased cell division activity in the condylar cartilage and additional sagittal growth during mandibular protrusion was found (McNamara et al. 1975, Stöckli, Willert 1971, Petrovic et al. 1974, Stutzman et al. 1986). Komposch (1982) observed a posterior rotation of the condyles, an increased cartilage layer in the posterior and resorption in the anterior zone of the condyle, anterior lengthening of the glenoid fossa with morphologic posterior translation of the ramus mandibulae.

Functional–orthopaedic appliances with various modifications were devised with varying success to make clinical use of the experimental evidence. The mode and extent of the skeletal response depend upon the morphology of the facial skeleton, the intensity and pattern of growth and the way of intervention. The therapeutic bite position determined by the construction bite is crucial to the remodellation processes to take place the TMJ area (Petrovic, Stutzmann 1988).

Bimaxillary appliances have increasingly been combined with extraoral devices, e.g., the activator plus headgear (Teuscher, 1976, 1978, 1979) or the bionator plus J-hook headgear (Witt, 1980, 1990) to enhance the effectiveness of treatment (Fig. 1a-c).

The “Wuerzburg Concept“

“Dropping out“ of the mandible during sleep is a common problem faced in bimaxillary appliance wear. Various modifications were suggested to counteract the problem of “dropping out“, e.g., magnets were built in double plates (Vardimon et al., 1989, 1990). According to the “Wuerzburg concept“, the therapeutic bite position on bionator wear in combination with extraoral traction is secured by up-and-down elastics during the night. This is a simple and well-tolerated method to effectively prevent the mandible from “dropping out“ during the night and, thus, to guarantee passive adaptation to take place during sleep. In connection with the anterior traction fixing the bimaxillary appliance to the maxilla and thus exerting a growth–inhibiting effect on the maxilla (Fig. 1 a-c), attachments are bonded to appropriate mandibular teeth (either canines, first premolars or first deciduous molars). Brackets or buttons are used for attachment, thus allowing for the insertion of elastics during the night. The latter run from these attachments to either the J-hooks balls or to the buccinator extensions of the bimaxillary appliance (Fig. 2).

While fixing the attachment, it has to be made sure that there is sufficient space between the buccinator extensions of the labial wire of the bimaxillary appliance (bionator) and the attachment. The elastics are selected so that the forces exerted on the mandible fall below 100g.

The mandible is kept in the therapeutic position determined by the construction bite at night by the up-and-down elastics (Fig. 2), thus providing the local conditions required for condylar growth adaptation (Petrovic et al. 1988).

The clinical effectiveness of treatment of Class II malocclusions according to the the “Wuerzburg concept“ was proved recently in a prospective study (Witt, Watted, 1999). Patients displaying Angle Cl. II div. 1 malocclusions (mean age 11.6 yrs.) and an initial required bite correction of 6 mm or more was treated according to the “Wuerzburg concept“ for 1 year and compared to matched controls left untreated for 2 years for several cephalometric parameters. The SNA angle was clearly reduced in the treated group from 82.2° to 81.6° ($\xi = -0.6°$). More importantly, the SNB angle significantly increased from 75.7° to 76.8° ($\xi = 1{,}1°$) in these patients. The corresponding reduction of the ANB angle averaged –1,7°, the facial convexity was reduced from 5,5 mm to 4,3 mm.

The Central Position of the Condyle and the Disco-condylar Relation

The definition of the physiologic position of the condyle in the fossa articularis and the disco–condylar relation is fundamental to the radiographic or MR–tomographic evaluation of the TMJ structures (Fig. 3). The variety of suggestions defining the physiologic, i.e., “correct“ position of the condyles has lead to confusion rather than to conceptual clarity (Posselt, 1952, Boucher, Jacoby, 1968, Celenza, 1973, Dawson, 1995, Gerber 1964, Kubein, Jähnig, 1983).

The Academy of Prosthodontics (1994) defined the centric relation as the spatial relationship between the maxilla and the mandible, where the condyles relate to the protuberantia articularis in a ventro–cranial position with the pars intermedia of the disc. The condylus mandibulae is physiologically located in the centre of the fossa mandibulae, with the cranial pole of the condyle and the most concave spot of the fossa mandibulae being located in the same vertical plane (Fig. 3). This approach is readily examined by means of MR tomography and was therefore employed in this study.

A disco–condylar relation with closed–mouth physiologic position of the condyle in the fossa is given, when the posterior pole of the disc is resting on the condyle in a 11–12 o’clock position. This topography corresponds to 0° – –30° with reference to the Y axis. With increasing mouth opening, the posterior pole of the disc moves further dorsally and is located in a 12–1 o’clock position with a mouth opening of 4 mm, corresponding to 0° – 30° with reference to the Y axis. Any deviation from these positions is referred to as disc displacement (Drace, 1989, 1990, Vogl, 1988) (Fig. 4 a, b).

If the mandible is moved into the intended sagittal, transversal and vertical therapeutic position to the maxilla by the construction bite, the position of the condyles is out of the centric. The condyles are moved ventrally from their central position within the mandibular fossa ventral in the direction of the tuberculum articulare. Accordingly, the disco–condylar relation changes. Of interest is the disco–condylar relation after bite–jumping having been completed by functional–orthopaedic treatment. While the position of the condyles after bite–jumping has been studied several times, the disco–condylar relation has yet to be cleared up.

Methods for the Study of the TMJ

The effects of a therapy concept exerted on the condyles and fossa can be assessed based on conventional roentgenologic procedures (e.g., radiographs of the TMJ using Schüller projection), panoramic X-ray (Bakke, Paulsen, 1989) or CT scans (Paulsen et al., 1995). However, only bony structures are visualized by these methods, while softtissue structures and particularly the discus articularis are not displayed. Moreover, the radioactive contamination is relatively high. The reproducibility of these recordings is questionable despite the use of reference patterns (Weinberg, 1970, 1972).

MR tomography is particularly suited for the assessment of fossa–disc– and disc–condyle relations. This method allows the determination of the morphological TMJ structures depending on mouth opening (Schellas et al., 1989, Tasaki et al., 1993, Vogl et al., 1988, Wilk et al., 1987) and the classification of various TMJ findings exiting in a given patient sample. Quantitative methods, however, are preferred for recognition of subtle differences in a largely normal study group.

Among the variety of relevant approaches (Bell, Yamaguchi, 1991, Braun, 1996, Drace, Enzmann, 1989, Gerber, 1971, Ismail, Rokni, 1980, Katzberg, 1983, 1985, Owen, 1984, 1992 und Weinberg, 1972,) a relatively simple and well–tried (Drace, Enzmann, 1990, Glatzl, 1993) method to determine the spatial disco–condylar relation was suggested by Katzberg et al. (1985). The so–called 12 o'clock position is referred to as the physiologic closed–mouth position of the disc.

The so–called 12 o'clock position is referred to as the physiologic closed–mouth position of the disc, as the transition of the pars posterior of the disc to the bilaminary zone is presumed to be located above the highest point of the condyle with closed mouth.

Moreover, the MR images allow to examine the (centric) position of the condyle in the fossa mandibularis after bite–jumping (Fig. 4). Again, various approaches were suggested. In contrast to the determination of the Joint Space Index developed by Kamelchuk et al. (1996), this study has relied on the approach described by Gerber (1970, 1978a,b) and utilized by Owen (1984). According to this approach, the zenith of the condyle is presumed to be located opposite to that of the fossa. This procedure allows a more reliable determination of the 3 reference points mentioned.

Aim

The evaluation of a treatment concept implies – beyond the appraisal of clinical effectiveness – the need to examine the condition of the temporomandibular joints. Therefore, this prospective study is designed to deal with the condylar shape and the position in the fossa mandibularis as well as the disco–condylar relation in terms of MRT findings after bite correction has been accomplished utilizing the "Wuerzburg concept".

II. Subjects And Method

Subjects

This study comprised n = 29 patients (mean age: 11,6 ± 0,5 years) showing Angle Class II div. 1 malocclusions and an initial need for bite–jumping of 6 mm or more who were treated with the bionator plus extra–oral traction and up-and-down elastics according to the "Wuerzburg concept" (Fig. 1 a, b, Fig. 2, Fig. 3). The patients were instructed to wear the appliance for 14 to 16 hours per day. The aids (extra–oral traction and up-and-down elastics) were prescribed only at night in order to leave daily functioning unaffected. Successful bite correction was necessary for inclusion in the study.

After 12 months and bite–jumping to the intended therapeutic position (T2) and prior to obtaining the intermediate records, a bite plane was applied for two weeks. With a prescribed daily wear of 24 h, this measure aimed at disclusion and muscular deprogramming (Fig. 5). Thus, the stability of the mandibular position was examined as to whether is was due solely to a muscular reaction or rather to growth adaptation of the bony structures. Moreover, the centric position of the condyles was thereby determined which was changed ventrally in the direction of the tuberculum articulare through the construction bite.

The cephalometric findings in comparison to untreated controls were reported earlier (Witt, Watted, 1999).

MRT examination

After discontinuation of the bite plane, MR images of the joints were obtained from 15 patients in order to study the shape of the condyles, the position of the condyles within the mandibular fossa, shape of the fossa and the disco-condylar relation. The MR images were provided in cooperation with the Institute of Radiodiagnostics, Dept. of MRT, of Wuerzburg University. The MR scans of the joints were produced according to the same procedure in all patients: both joints were scanned with open mouth and with closed mouth, i.e. habitual (neutral) occlusion. For fixation of mouth opening during the scans a plastic wedge was inserted between the arches in all patients. The MR scans were obtained by means of a 1,5T high field scanner (Siemens Magnetom Vision) with a special surface coil (TMJ coil). An optimized proton-weighted TSE (turbo factor 5) sequence (TR 1600ms, TE 15ms) in an angulated parasagittal position with a slice thickness of 3 mm and an 512 matrix (Field-of-view 170 mm) was used (Fig 6). The mean measuring time was 2:08 min after triple averaging.

The analysis of the MR images of the 30 joints was conducted by means of a PC (Scion Image ver. 3b). The central position of the condyles in the mandibular fossa and the disco-condylar relation were analyzed. Both parameters were assessed according to the above-mentioned definitions by Gerber (1971) and Vogl et al. (1988). This topographic definition was measured and visualized in terms of angle degrees.

Position of the condyles:

To assess the spatial relationship of the zeniths, the longitudinal axis of the condyle was determined as follows: the anterior and posterior pole of the condyle was established (both are readily recognized on the MR image). A connecting line is drawn between these points of reference. From the centre of this line, a perpendicular line is dropped cranially (Y axis) intersecting the cranial pole of the (sound) condyle. Another line is drawn from the constructed centre to the centre of the mandibular fossa which is defined as the point of maximum concavity (Fig. 7). If the two lines coincide, the condylus is in a centric position, i.e., in its ideal physiologic position within the mandibular fossa. If an angle is formed by the two lines, the condyle is in a posterior (positive values) or anterior position (negative values) according to the definition of the centric position after Westesson, Vogl and Gerber.

Disco-condylar relation: The disco–condylar relation was assessed with open and closed mouth. After determination of the longitudinal axis of the condyles (Y axis), the posterior pole of the disk was marked. A line was drawn between the constructed centre in the condyle and the posterior pole of the disk. Provided a physiologic disco–condylar relation, this line forms an angle with the Y axis of 0° to –30°, i.e., 11 to 12 o'clock position, with closed mouth, and 0° to +30°, i.e., 12 to 1 o'clock position, with open mouth (up to 40 mm) (Fig. 4 a, b, Fig. 7).
The shape of the condyles and the mandibular fossa was assessed visually.

III. Results

Clinical analysis

Functional analysis showed no pathologic changes or functional restrictions of the joints and muscles. No patient displayed a conspicuous discrepancy between the occlusion achieved through bite–jumping and the centric position before and after insertion of the bite plane indicating skeletal and muscular adaptation and, hence, a stable position of the mandible. Existing dysfunctions, e.g. of the lip, were eliminated by the reduction of the overjet (see Witt, Watted, 1999).

MRT analysis

Shape of the condyles and the fossa: The MR images show a physiologic shape of the fossa and the condyles with both open and closed mouth. These structures were judged visually by two radiologists independently.

Disco-condylar relation: The analysis of the MR images revealed a physiologic disco–condylar relation in all patients. With closed mouth, the disk was located in relation to the condyle at a position of –18,8° ± 3,9° on average with reference to the Y axis. The maximum deviation of the disk from the "0 point" was –27,2°, the minimal deviation was –12,1°.

With open mouth, the disc was located in relation to the condyle at a position of +25° ± 5,2° on average, with a maximum deviation of +32,1° and a minimal deviation of +14,9° (Table 1, Graphic 1).

	N	Min/Max	Mean	Standard dev.
MR1 (closed)	**30**	**-12,1°/-27,2°**	**-18,8°**	**±3,9°**
MR2 (open)	**30**	**+14,9°/+32,1°**	**+25,3°**	**±5,2°**

Table 1: Position of the disc in relation to the condyle

Position of the condyles (centric position): 55 % of the condyles displayed a deviation with reference to the "0 point" or Y axis, i.e., the zenith of the condyle was located dorsally or ventrally from the Y axis. 75 % of the condyles showed a dorsal deviation from the Y axis (positive value) and 25 % a ventral deviation (negative value). The deviation from the centre of the mandibular fossa averaged +0,5° ± 1,5°, with a minimum of –3° and a maximum of +3° (Table 2, Graphic 1)

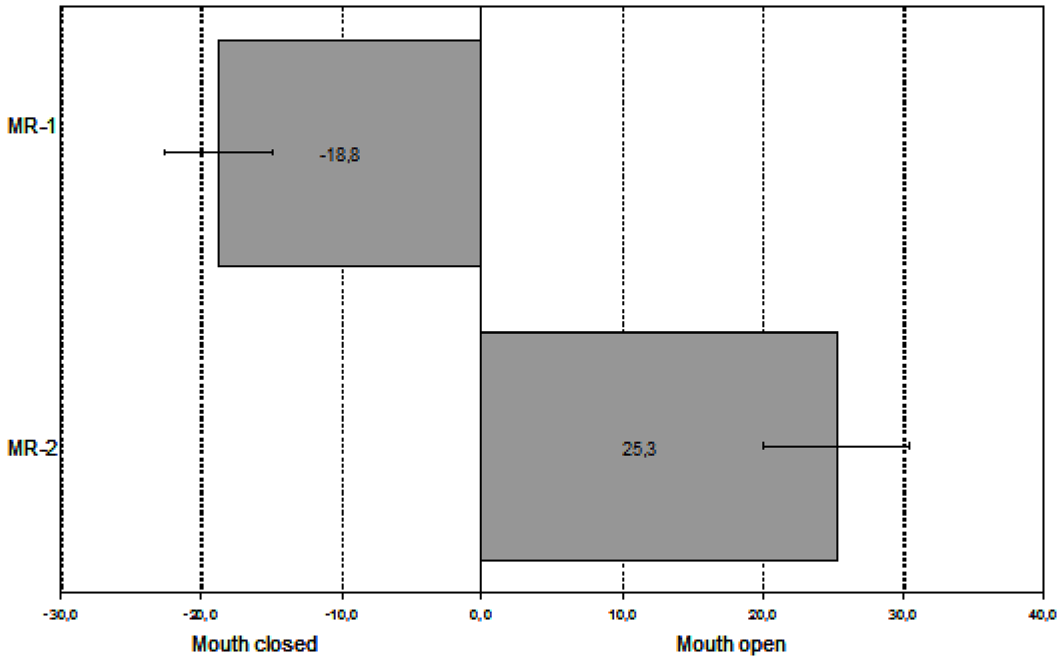
	N	Min/Max	Mean	Standard dev.
MR1 (closed mouth)	**26**	**-3°/+3°**	**+0,5°**	**±1,5°**

Table 2: Position of the condyle in relation to the mandibular fossa after bite–jumping (closed mouth)

IV. Discussion

Treatment according to the "Wuerzburg concept" leads to stimulation of mandibular growth and an inhibition of maxillary growth. Growth stimulation is enhanced, when the mandible is secured in the bite position which was shown in a control study (Witt, Watted, 1999). This effect is due to the mandible being prevented from dropping out of the "therapeutic position" during sleep by means of up-and-down elastics. Thus, the local conditions needed for the adaptation, remodellation and morphologic translation of the joint structures and their surroundings are provided. In the above-mentioned study adaptation proved to depend upon the time interval during that the mandible and the condyle were kept in the intended position.

Our findings are in accordance with earlier findings from animal experiments (Baume et al. 1961, Charlier et al. 1969, Stöckli, Willer, 1971, Stöckli, 1972, Derichsweiler, 1958, Komposch, 1982, McNamara, 1972, 1975, Petrovic, 1975, 1976, 1988, Payne, 1971, Stutzmann et al., 1975, 1986) and clinical trials (DeVincenzo, 1987, Eschler, 1952, 1954, 1963, Hotz, 1970, Korkhaus, 1960) regarding the effects of functional–orthopaedic appliances (Fig. 8).



Graphic 1: Position of the disc in relation to the condyle (closed and open mouth)

After bite–jumping and initial ventral movement of the condyles from the fossa toward the tuberculum articulare by means of the construction bite, a physiologic shape and position of the condyles and the mandibular fossa were seen in the MR images (Fig. 9 a-d, Fig. 10 a-d, Fig. 11 a, b).

MR tomography is not considered the method of choice for the assessment of bony appositions, since the width of the corical signal is sequence-dependent, i.e. depending on the susceptibility of the given sequence to artifacts at the spongiosa–corticalis–cartilage–interface, and is additionally influenced by the window size (Preidler et al., 1997). Even under identical measuring conditions, a reliable assessment of the pre–/post–treatment bony appositions – which amount to 1–2 pixels within the common resolution – is doubtful.

Celenza (1973) and Calagna et al. (1973) found that after muscle training or prolonged splint wear patients could move the mandible dorsally beyond the hinge position. This observation is relevant to our findings regarding the position of the condyle in relation to the mandibular fossa.

A posterior position (positive value) was found in 75 % of the joint deviations from the Y axis. These findings are inconsistent with other studies reporting an anterior position of the condyles after "bite–jumping" (Ruf et al 1998). The posterior position of the joints found in our study is probably due the bite plane inserted for 2 weeks (Williamsone et al 1977, 1978). It served both the disclusion and deprogramming of the muscles and may have caused a dorsal movement of the joints. In contrast, the images of the joints used in former studies were produced no later than 4 days after discontinuation of the treatment devices by which the mandible was kept in a permanent ventral position and, consequently, the muscles were adapted. This position of the mandible is maintained for some days without muscular deprogramming and disclusion, if no bony adaptation and remodellation have taken place.

V. Conclusion

The results revealed the following: (1) during the one-year treatment period the sagittal dental arch relationship improved, but a class I occlusion could not be achieved in all patients; (2) on average, a physiologic position of disc, condyle, and fossa was present both before and after one year of Activator treatment; (3) a pretreatment physiologic disc-condyle relationship was unaffected by Activator therapy; 4) a pretreatment disc displacement could not be repositioned during Activator treatment; (5) the prevalence of a subclinical capsulitis of the inferior stratum of the posterior attachment increased during Activator treatment; and (6) the degree of compliance had no influence on the disc-condyle relationship or the reaction of the posterior attachment of the TMJ.

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Captions to the figures

Fig. 1 a: Patient with anterior traction, mouth-closing not restricted.

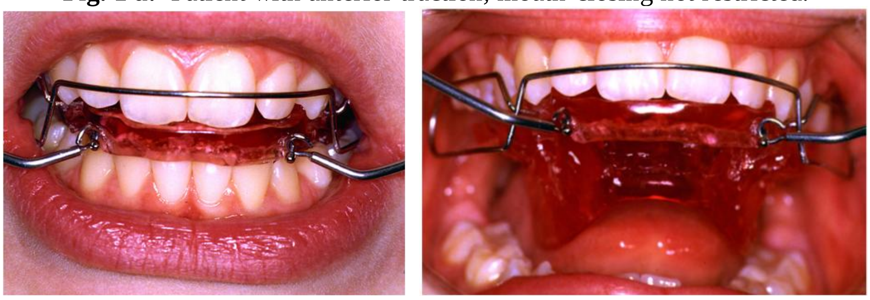

Fig. 1 b, c: Bionator with anterior traction, fixation of the appliance to the maxilla by the anterior traction; the bionator must not drop from the upper lateral teeth on mouth-opening.

Fig. 2: Treatment combination, anterior traction for fixation of the appliance to the maxilla with up-and-down elastics for securing the mandible in the bite position

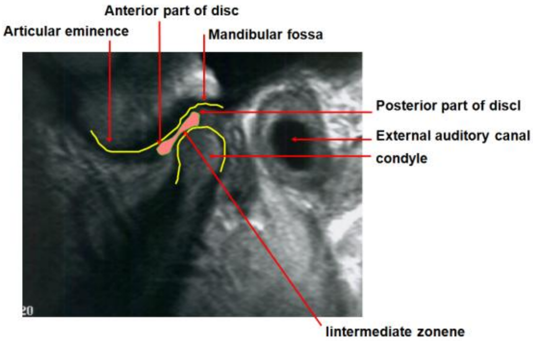

Fig. 3: MR image witg graphical visualization of the structures in question

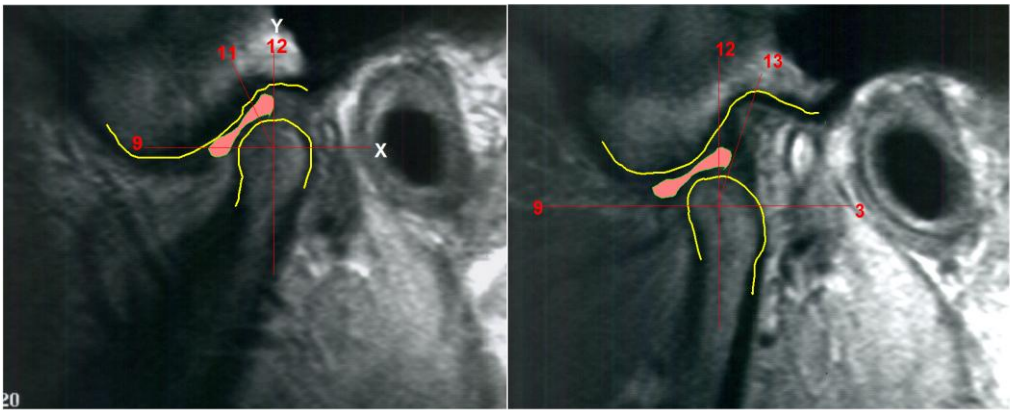

Fig. 4: MR image of a sound temporomandibular joint in the centric relation, physiologic position of the condyles and disco–condylar relation with closed mouth *(a)* and open mouth *(b).*

Fig. 5 : Bite plane (splint) designed for disclusion after bite-jumping and control of bite stability

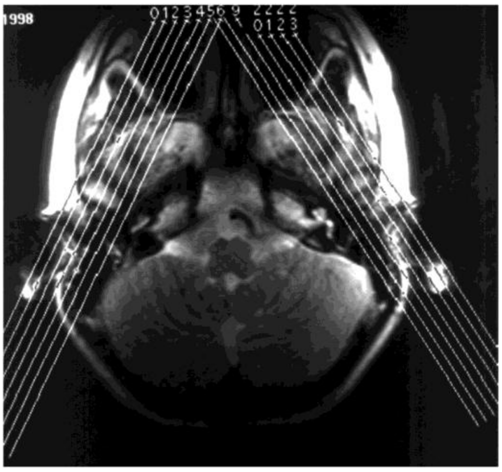

Fig. 6: Angulated parasagittal slices, thickness 3mm, for MR imaging

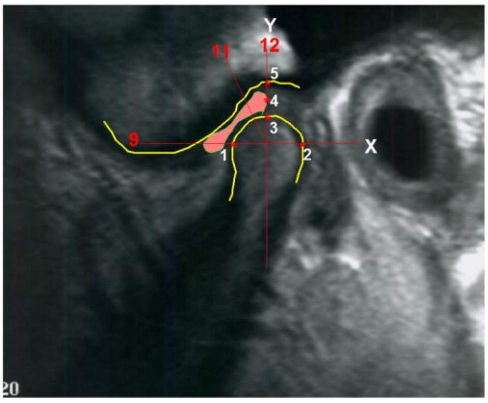

Fig. 7: Reference points for measurement
1, 2: anterior and posterior pole of the condyle
3: cranial pole of the condyle (der höchste Punkt des Köpfchens) des Kondylus
4: posterior pole of the disc
5: centre of the fossa mandibularis

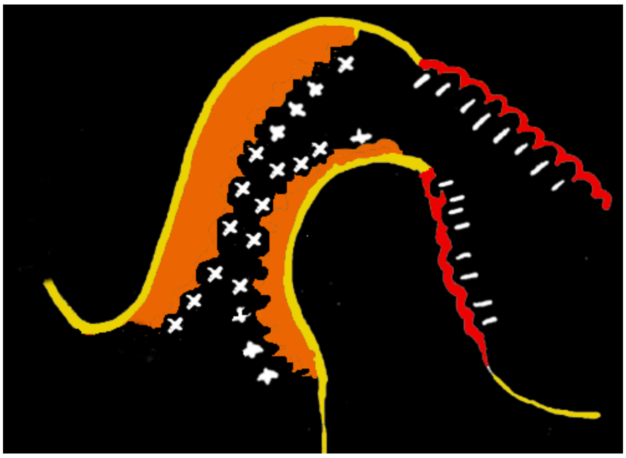

Fig. 8: Mechanisms of remodellation of the condyle; bone apposition in dorsal condyle and in the posterior curvature of the fossa mandibularis, bone resorption in the ventral condylus and in the anterior curvature of the fossa mandibularis.

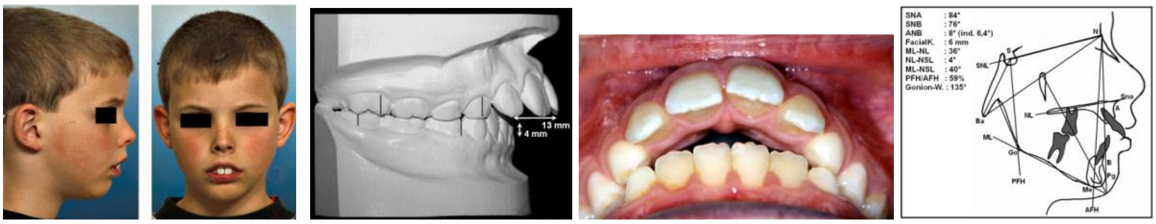

Fig. 9a-d: *a-c*: 9,5-year-old patient before the onset of treatment
d: Lateral cephalogramme obtained at this time

Fig. 10a-c: Clinical situation after bite correction and 3 weeks after insertion of a bite plane

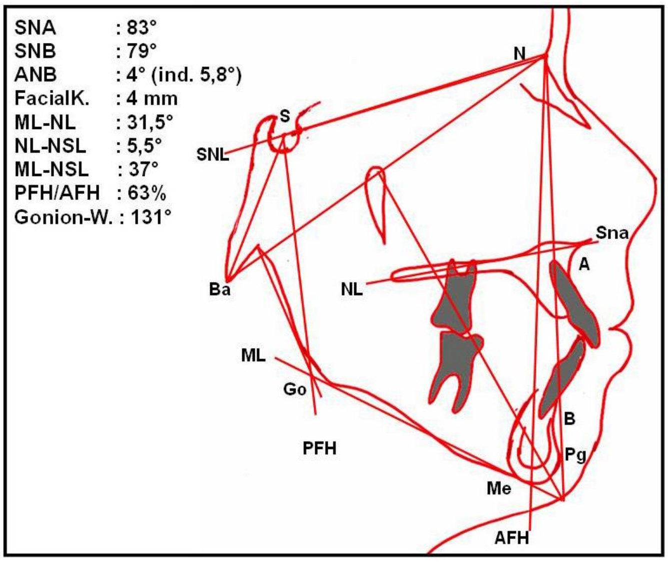

Fig. 10d*:* Lateral cephalogramme obtained at this time

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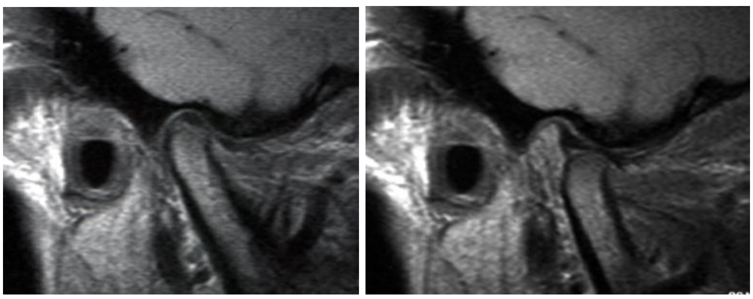

Fig. 11 a, b: MR images of the same patient after bite correction and insertion of a bite plane; physiologic position of the condyles and disco–condylar relation
a: with closed mouth
b: with open mouth