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Established prosthodontic rules confirmed in natural adolescent occlusion

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Abstract Guidelines have been established for the arrangement of artificial teeth based on the curve of Wilson, the curve of Spee and the occlusal plate rule of Gysi. However, no scientific studies have been carried out to see whether these prosthodontic rules are actually present in natural teeth. This study was carried out on a selected sample of children and adolescents with natural dentitions using a 3D computer-aided measuring device to reevaluate these occlusal rules in order to establish whether occlusion with anterior protected articulation is the occlusal scheme of choice. The previously estblished prosthodontic rules were confirmed to be present in the complete natural dentitions of adolescents at completion of tooth eruption period and support their use as guiding principles in diagnosis and treatment.

Keywords: Adolescent, Dental occlusion, Dental models, Occlusal guidance, Occlusal wear

Introduction

Much has been written about various occlusal concepts, occlusal curves, function related to the anatomy of teeth and the arrangement of teeth in the dental arches. Some of these rules, such as the curve of Spee [1], anteroposterior curve [2], the curve of Wilson [3], mediolateral curve [2] and the occlusal plate rule of Gysi [4] are well established in prosthodontic concepts. The curve of Spee is established by the occlusal alignment of the teeth as projected onto the median plane. Beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth the curve continues through the anterior border of the mandibular ramus and ends with the most anterior portion of the mandibular condyle. The curve of Wilson is described as the curvature of the buccal and lingual cusps as projected on the frontal plane. Alfred Gysi described a simplified rule for arranging artificial teeth [4]. This occlusal plate is defined through the maxillary incision, the midpoint between the mesial incisal edges of the two maxillary central incisors. The other two points which define this plate are the two mesiolingual cusp tips of the maxillary first molars. When a simple plate of glass is placed on the maxillary dental arch per definition the maxillary two central incisors and two mesiolingual cusps of the first molars should contact the glass plate as well as the tips of canines and the buccal cusps of first and both cusps of second premolars. The lateral incisors as well as lingual cusps of first premolars should not reach the plate. As cusp tips of first and second molars follow the anterioposterior and mediolateral curves only the mesiolingual cusps of the first molar should have contact with the plate while all other cusps do not reach the plate. This rule has provided a simple guideline for the arrangement of artificial teeth which fulfills both esthetic and functional demands. Conversely, it is claimed that none of these concepts or curves have ever been scientifically reported to be present in natural dentition [5]. Recording the 3-dimensional arrangement of complete natural dentitions is an approach to confirm whether these essential guidelines exist in nature. Given that support of these guidelines is found, this in turn would support their application when orthodontic treatment, prosthetic restoration or preprosthetic orthodontic treatment is intended.

A review of the literature from the past 25 years (from 1976 to 2001) through Medline reveals that there have been some attempts to quantify functional parameters of occlusion and occlusal concepts by means of scientific data. Ferrario et al. [6, 7] investigated the 3D curvature of the mandibular dental arch (the radii of the curve of Spee, the curve of Wilson, and Monson's sphere) in permanent dentitions of human adolescents and adults. The mean of the radii of the overall sphere, the right and left

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curves of Spee and the curve of Wilson in the molar area was 101 mm in adults, and 80 mm in adolescents. Arch size was not influenced by either gender or age. Orthlieb [8] investigated the curve of Spee and found a radius of 83 mm (±22 mm). Furthermore, Orthlieb showed that the long axis of the mandibular incisors followed the tangent law [8] but the long axis of the posterior mandibular teeth exhibited a progressive differential angle (postero-anterior) with the direction of the tangent. This differential angle was suggested to generate a horizontal strength component with tendency to forward tooth movement and tightening of the interproximal tooth contacts.

Kulmer et al. [9] measured the inclination and the length of occlusal guiding elements in natural untreated dentitions and [9] concluded that the concept of a sequential laterotrusive guidance with dominance of the canines and the anterior teeth (anterior and canine-guided occlusion or mutually protected occlusion) was the guidance scheme primarily represented in these occlusions. It has been reported that occlusions with anterior canine guidance allow less muscular activity and forces within the stomatognathic system during parafunction than occlusions with group function patterns and balanced occlusions [10–19].

For long-term success and stability it has been suggested that an occlusal concept be established which keeps the muscular activity of the patient at the lowest level and thereby prevents the stomatognathic system from dysfunction or possibly self-destruction [20, 21]. These references suggest that this is best accomplished by an anterior protected articulation (mutually protected articulation; [2]), even for complete dentures [15, 22–25]. These studies suggest that it would be worthwhile to re-evaluate previously accepted occlusal rules in order to establish whether occlusion with anterior protected articulation is the occlusal scheme of choice.

In this study casts of a selected sample of children and adolescents with natural dentitions were investigated using a 3D computer-aided measuring device. An attempt was made to quantify the characteristics of the curve of Spee [1], the curve of Wilson [3], and the occlusal plate rule of Gysi [4] using the 3D arrangement of teeth in the dental arches. The purpose of this investigation was to assess whether established occlusal rules are present at completion of the tooth eruption period.

Material and methods

A cross-sectional investigation of 108 Tyrolean children and adolescents (aged 6 to 16 years) with natural dentition was performed at the University Hospital of Innsbruck [26]. In group 3 (age 13 to 16 years) there were 41 casts and of this collective 34 pairs of casts (23 female, 11 male) were selected by the following inclusion criteria: all permanent teeth from the central incisors to the second molars had to be fully erupted and in occlusal contact with their antagonists. Exclusion criteria were malocclusion, i.e. reverse articulation, buccal or lingual non-occlusion but most had to be rejected because the second molars had not fully erupted and were not in occlusal contact. The mean age of the selected population was 14.2 ± 1.12 years ranging from 13 to 16 years. Irreversible hydrocolloid (Xantalgin select, Haereus, Wertheim, Germany) impressions were made of the maxillary and mandibular arches and poured immediately in class IV stone (Silky Rock; Whip-Mix Corp, Louisville, KY).

The kinematic axis was determined according to Lauritzen and Bodner [27] and marked on the skin. The left infraorbital notch was chosen as the third reference point. The reference plane used was the axis-orbital plane (AOP). The maxillary (split) cast was mounted to this axis-orbital plane with a face-bow (Almore International, Portland, OR) in a SAM 1 articulator (SAM, Munich, Germany). The mandibular cast was mounted by means of a patient-derived interocclusal wax mould [28]. The patient was brought into the centric relation position and then closed the mandible the last millimeters into the intercuspal wax mould himself. Thereby the force vector on the condyles was superior and anterior. This positions the condyles on the thinnest avascular portions of the discs and the condyle-disc complexes in the anterior-superior position against the shapes of the articular eminences (patient determined intercuspal wax record).

For analysis the casts were mounted in a computer-assisted 3D digitizer (Gamma, Klosterneuburg, Austria). The digitizer was calibrated so that the coordinate system of the SAM 1 articulator and that of the digitizer were identical for all maxillary casts [9]. As the mandibular casts were mounted with an interocclusal record, in most situations the incisal pin of the articulator was not exactly zero in maximum intercuspation. When the incisal pin is not at zero in maximum intercuspation the mandibular cast changes its angulation when it is mounted into the 3D-digitizer. This error was corrected for x and z coordinates depending on incisal pin offset by our digital measuring system. The measuring tip was placed on each predetermined measuring point allowing all coordinates to be recorded electronically. The ballpoint measuring tip was 1 mm in diameter. To enhance precision an additional light source and a 2-fold magnifying glass were used (Carl Zeiss, Oberkochen, Germany). The same data-processing software developed for the Kulmer et al. study was used. In a previous study using the same measurement system on 3 different casts 12 landmarks were digitized and distances between pairs of landmarks were calculated. Following recalibration each measurement was repeated 10 times. In that previous study a standard error of the mean of 0.05 mm for distances was reached by a trained investigator [9]. An operator training study prior to this investigation was performed on one cast with the same conditions and a 0.09 mm standard error of the mean was reached by the investigator who performed the presented study.

Landmarks of measurement

For maxillary casts the mesial and distal incisal edge points of the central and lateral incisors, the tips of canines and the buccal cusp tips of premolars and molars were digitized. The cusp tips of the lingual cusps of the maxillary premolars and molars were also digitized (Fig. 1).

The corresponding landmarks were digitized in the mandibular area (Fig. 1). The points of measurement on the lingual surfaces of the maxillary anterior teeth according to Kulmer et al. [9] are shown in Fig. 2. For the statistical evaluation the points F1r and F2 were used.

Reference planes

For the measurements of the coordinates all casts were mounted in relation to the AOP as described. For a better illustration of the investigated data, the maxillary occlusal plane ("occlusal plate"; [4]) was chosen which is defined by the mesiolingual cusp tips of the maxillary first molars and the middle of the mesioincisal edges of the central incisors. All coordinates measured for the maxillary arch were calculated in relation to this reference plane. The occlusal plane, defined by the mesial incisal edges of the mandibular central incisors and the distobuccal cusp tips of the mandibular first molars, was used as the reference plane for the data display in the mandibular arch.

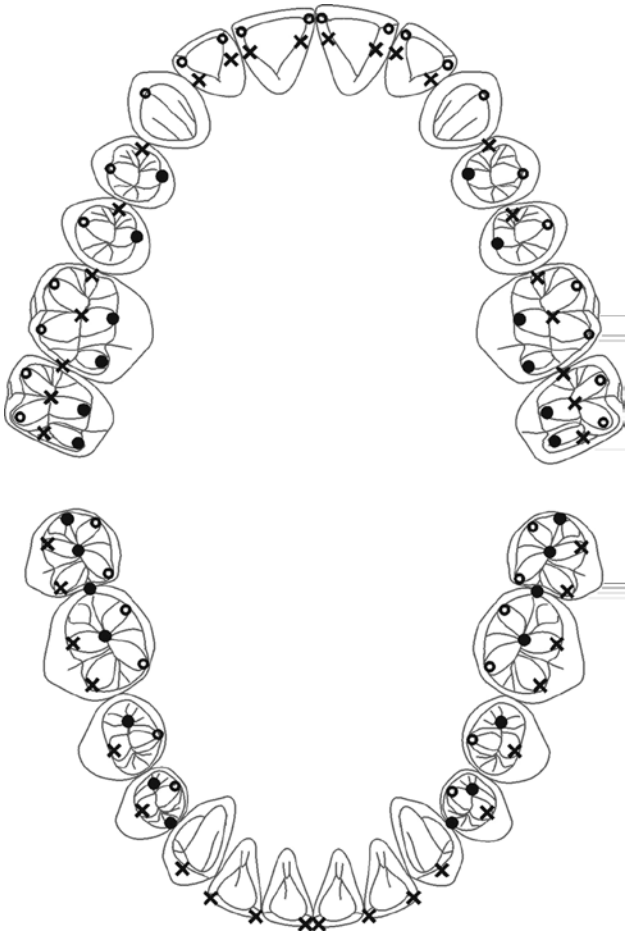

Fig. 1 Digitized landmarks on maxillary and mandibular teeth. For investigation of the curve of Spee, the curve of Wilson and the maxillary occlusal plane, mesial and distal incisal points of incisal edges of maxillary anterior teeth, canine cusp tips and buccal cusp tips of maxillary premolars and molars (*open circles*) were digitized. In addition lingual cusp tips of maxillary premolars and molars (*filled circles*) were digitized. Incisal edges of mandibular incisors, canine tips and buccal cusp tips (*crosses*) as well as lingual cusp tips (*open circles*) of mandibular posterior teeth were digitized

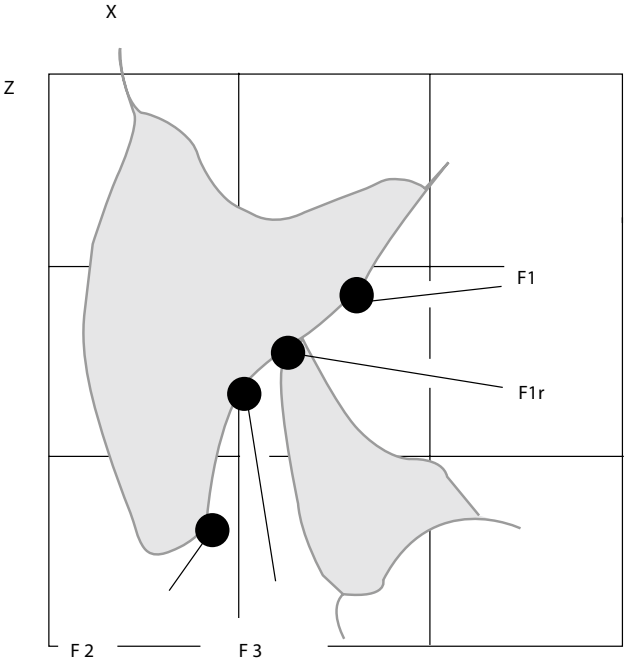

Fig. 2 $F1r_{(real)}$ is the point where the incisal edge of mandibular incisors contacts lingual concavity of maxillary incisor lingual surface (starting point), *F1* is the tangential turning point from lingual concavity to convexity of cingulum, *F2* is the functional end point of anterior guidance at intersection of lingual concavity and lingual edge of incisal surface of maxillary incisors and *F3* is the deepest point of lingual marginal ridges of maxillary incisors

Statistical methods

Descriptive statistics, including the mean, standard deviation, range, median, and first and third quartile, were calculated for the positions of cusps and incisal edges and distances measured between dental landmarks and reference planes mentioned above.

Paired t-Tests were used for multiple testing with following Bonferroni correction for side to side comparisons. One-way ANOVA was used for multiple testing when applicable. P-values less than 0.05 were considered to be significant. All values were expressed as mean ± standard deviation.

Results

Table 1 gives the mean and standard deviation in millimeters of the distances of the incisors, canine tips and buccal and lingual cusp tips of the premolars and molars to the mandibular occlusal plane. Figure 3 shows the distances of the mandibular canine tip and the buccal cusp tips of premolars and molars to the occlusal plane. The greatest mean distances to the occlusal plane were found for the second premolars (−0.64 mm, SD±0.50 mm) and at the mesiobuccal cusps of the first mandibular molars (−0.66±0.43 mm). The tips of the canines were clearly located above the occlusal plane (±0.46±0.62 mm). Following the characteristic of the anteroposterior curves, increasing positive values were found for the mesiobuccal and distobuccal cusp tips of the second molars.

The coordinates of the mandibular canine tips and the buccal cusp tips of the premolars and molars were measured relative to the AOP. According to this data the radius of the curve of Spee were extrapolated for the right and left side (Fig. 3). The mean value of the radius for both sides was 68.5 mm showing a relatively large standard deviation of ± 20.9 mm (Table 2).

Projections of the right and left maxillary and mandibular premolars and first and second molars in the frontal plane are shown in Figs. 4 and 5 to represent the mediolateral curve (curve of Wilson). The reference plane used was the occlusal plane for the maxilla and the occlusal plane for the mandibular arch. For the premolars the buccal and lingual cusps are displayed simultaneously in one section. For the molars separate sections showing the mesiobuccal and mesiolingual cusps and sections showing the distobuccal and the distolingual cusps are displayed. These molar sections were created for better illustration since a single projection of two cusps in any plane parallel with the frontal plane was not possible. The numbers indicate the difference in millimeters between the lingual and buccal cusps measured to the reference plane.

The lingual cusps of the first maxillary premolars were on average 0.67 ±0.69 mm (right side) and 0.78±0.78 mm (left side) above the buccal cusps so the connecting curve of the cusp tips showed a concave characteristic. The mean difference between buccal and lingual cusps of the second premolars was 0.05±0.05 mm right and left resulting in a straight line connecting the cusp tips. The turning point from a concave to a convex characteristic of the cuspal connecting line is located in the region of the second premolars. In the maxillary molar region a clear convexity of the connecting curve is visible. The

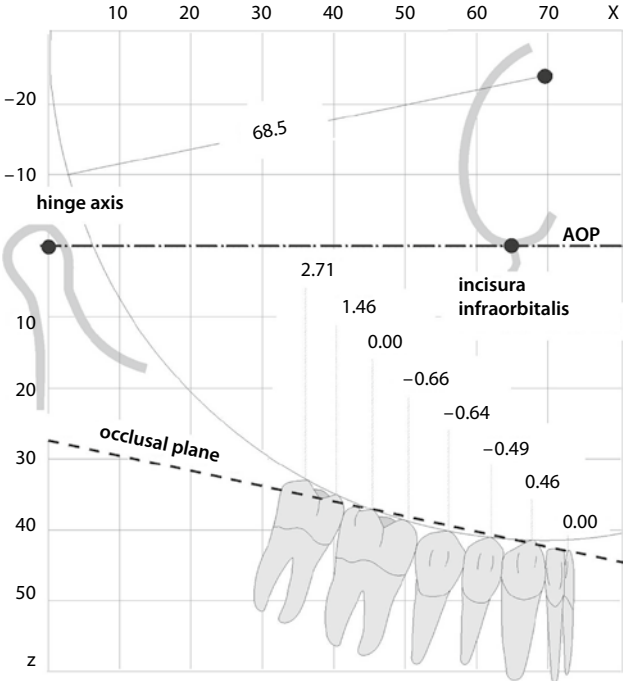

Fig. 3 Curve of Spee. Sagittal projection of distances in millimeters of mandibular buccal cusp tips, canine tips and incisal edges to occlusal plane. Kinematic axis point is zero point of coordinate system; axis orbital plane (AOP) is reference plane. Positions of teeth are displayed in exact relationship with coordinate system. Negative values indicate that teeth do not reach occlusal plane

Table 1 Mean (standard deviation) of distances to occlusal plane in mandible (Measurement unit: millimeter, negative values: incisal edges and cusp tips are located below occlusal plane, positive values: incisal edges and cusp tips lie above occlusal plane)

Mandibular teeth		Both sides	
		Mean	SD
Central incisors		0.00	(0.16)
Lateral incisors—distal		−0.12	(0.49)
Canines		+0.46	(0.62)
First premolars	Buccal cusp tip	−0.49	(0.57)
	Lingual cusp tip	−2.46	(0.75)
Second premolars	Buccal cusp tip	−0.64	(0.50)
	Lingual cusp tip	−1.91	(0.78)
First molars	Mesiobuccal cusp tip	−0.66	(0.43)
	Mesiolingual cusp tip	−0.95	(0.54)
	Distobuccal cusp tip	0.00	(0.00)
	Distolingual cusp tip	−0.46	(0.48)
Second molars	Mesiobuccal cusp tip	+1.46	(0.52)
	Mesiolingual cusp tip	+0.18	(0.78)
	Distobuccal cusp tip	+2.71	(0.71)
	Distolingual cusp tip	+1.40	(0.97)

Table 2 Mean (mm and standard deviation) radius of mandibular anteroposterior curve (curve of Spee) in comparison with values from Spee [1] and Orthlieb [8]

Right	Left	Both	Comparative values from literature	
			Spee ([1])	Orthlieb ([8])
68.9 (18.8)	68.2 (22.5)	68.5 (20.9)	65–70	83 (21.7)

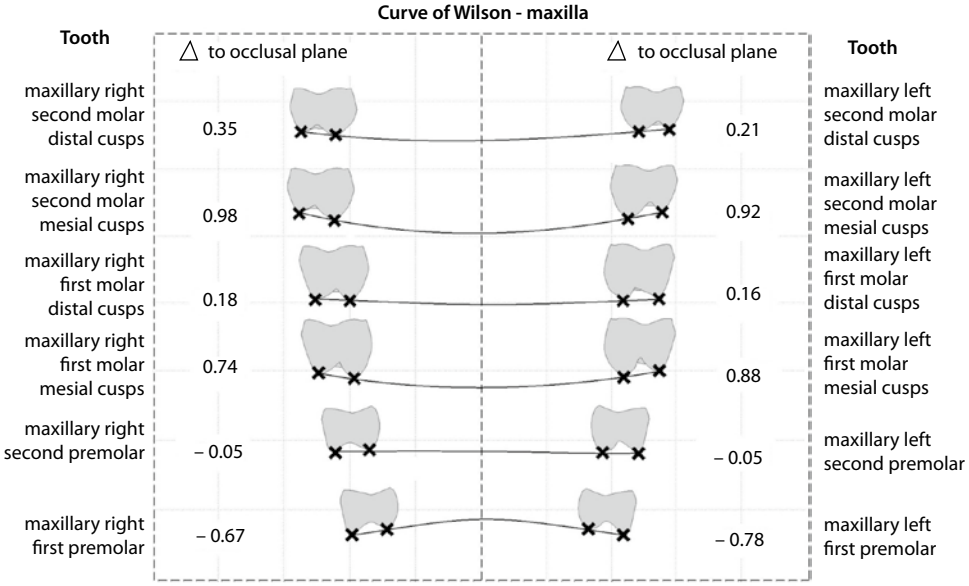

Fig. 4 Curve of Wilson, maxilla. Projection of cusp tips *(x)* of maxillary premolars and molars in frontal plane and interpolated curves of Wilson. Numbers indicate the difference between buccal and lingual cusp tips measured to maxillary occlusal plane in millimeters. Negative values indicate that lingual cusp is shorter than buccal cusp

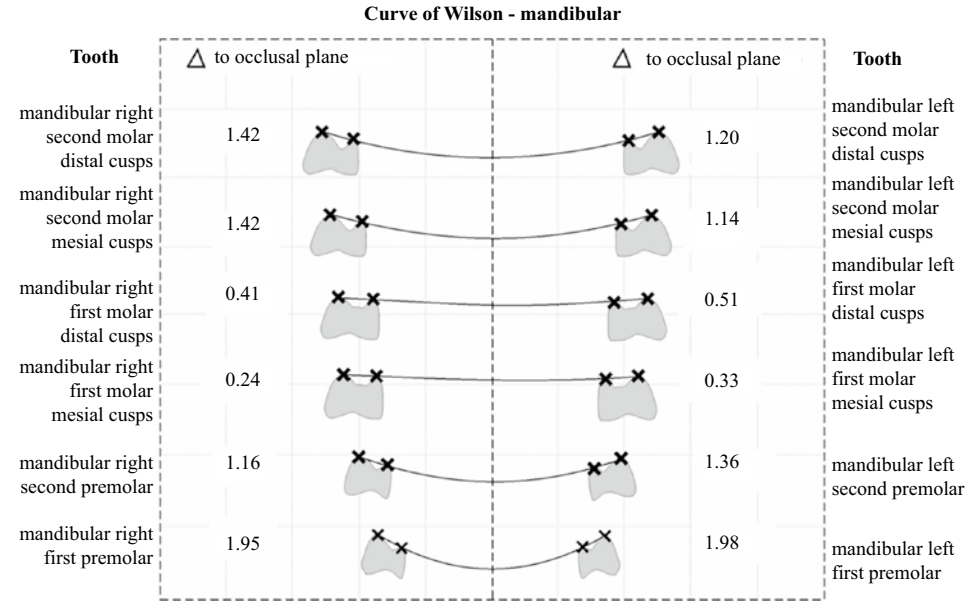

Fig. 5 Curve of Wilson, mandibular. Projection of cusp tips *(x)* of mandibular premolars and molars in frontal plane and interpolated curves of Wilson. Numbers indicate difference between buccal and lingual cusp tips measured to mandibular occlusal plane in millimeters

differences of the means measured between the mesiolingual and mesiobuccal maxillary cusps ranged from 0.74±0.53 mm–0.98±0.56 mm and were greater than the differences between the distolingual and the distobuccal cusps (0.16±0.51 mm–0.35±0.69 mm; Fig. 4).

A concave characteristic of the mandibular cuspal connecting line (mediolateral curve) can be found in the premolars as well as in the molars (Fig. 5). The greatest differences between the lingual and buccal cusps were measured in the first premolars with 1.95±0.67 mm (right side) and 1.98±0.62 mm (left side) resulting in a deep concavity of the curve. The smallest differences were found in the first molars (0.24±0.47 mm–0.51±0.50 mm), resulting in a flattening of the curve in this region. Increasing differences between buccal and lingual cusps were observed in the second molars (1.14±0.42 mm–1.42±0.51 mm).

The mean distances between reference points to the maxillary occlusal plane are shown in Table 3. By definition the maxillary central incisors and the mesiolingual cusps of the first molars contacted the plane. Negative values indicate that the tooth was positioned above the maxillary occlusal plane. The lateral incisors were located 0.82±0.54 mm–0.88±0.65 mm above the occlusal plane. The tips of the canines and the buccal cusp tips of the first premolars were in contact with the plane, whereas the lingual cusps of the first premolars were approximately 0.72±0.92 mm above the maxillary occlusal plane. Both the buccal and the lingual cusps of the second premolars showed nearly the same length and came close to the plane. The mesiolingual cusps of the first molars were by definition the only molar cusps in contact with the plane. All other cusps of the first molars showed dis-

Table 3 Mean (in mm, standard deviation) of distances to maxillary occlusal plane (occlusal plate rule according to Gysi [4]). *F2* functional end point of anterior guidance of central and lateral incisors at intersection of lingual concavity and lingual edge of incisal surface of maxillary incisors (positive values: incisal edges and cusp tips are above maxillary occlusal plane, negative values: incisal edges and cusp tips are below maxillary occlusal plane)

Maxillary teeth		Both sides	
		Mean	SD
Centrals	Mesial F2	0.00	(0.24)
	Distal F2	+0.10	(0.42)
Laterals	Mesial F2	+0.82	(0.54)
	Distal F2	+0.88	(0.65)
Canines	Cusp tips	−0.10	(0.75)
1st Premolars	Buccal cusp tips	−0.19	(0.65)
	Lingual cusp tips	+0.53	(0.92)
2nd Premolars	Buccal cusp tips	+0.08	(0.55)
	Lingual cusp tips	+0.14	(0.63)
1st Molars	Mesiobuccal cusp tips	+0.81	(0.51)
	Mesiolingual cusp tips	0.00	(0.00)
	Distobuccal cusp tips	+0.72	(0.69)
	Distolingual cusp tips	+0.55	(0.47)
2nd Molars	Mesiobuccal cusp tips	+2.47	(0.85)
	Mesiolingual cusp tips	+1.52	(0.81)
	Distobuccal cusp tips	+3.68	(1.04)
	Distolingual cusp tips	+3.40	(1.21)

tances ranging from 0.55±0.47 mm for the distolingual cusps to 0.81±0.51 mm for the mesiobuccal cusps above the maxillary occlusal plane. The second maxillary molar had no contact with the plane.

For the central incisors the vertical overlap measured 4.1±1.4 mm and the horizontal overlap 2.6±0.8 mm. Of the mandibular incisors 85% contacted the maxillary incisors at the flat part of the lingual concavity between F1 and F3 (F1r) and in 15% of subjects a contact was found at the steep part between F3 and F2 (Fig. 2).

The relationship between the functional esthetic line (connecting the maxillary incisal edges, canine tips and buccal cusp tips of the premolars and molars) and the line connecting the centric stops of the mandibular incisal edges, canine tips and buccal cusp tips of premolars and molars in the maxillary teeth is displayed in Figs. 6a, b. In addition the connecting line of the maxillary lingual cusp tips is drawn in both figures. Projected in the AOP a clear horizontal overlap is visible for anterior teeth as well as for premolars and molars. Projected in the sagittal plane (x/z plane), a continuous decrease of the vertical overlap can be observed from the anterior teeth to the second premolars which are at equal height. In the sagittal projection the line of the lingual cusps in the molar region is located below the functional esthetic line thus representing a lingualized contact occlusion in these natural dentitions.

The occlusal table is defined as the portion of the occlusal surface of posterior teeth that lies within the perimeter of the cusp tips, the cusp ridges and the marginal ridges. The width of the occlusal table was measured for each tooth as the distance between the buccal and the

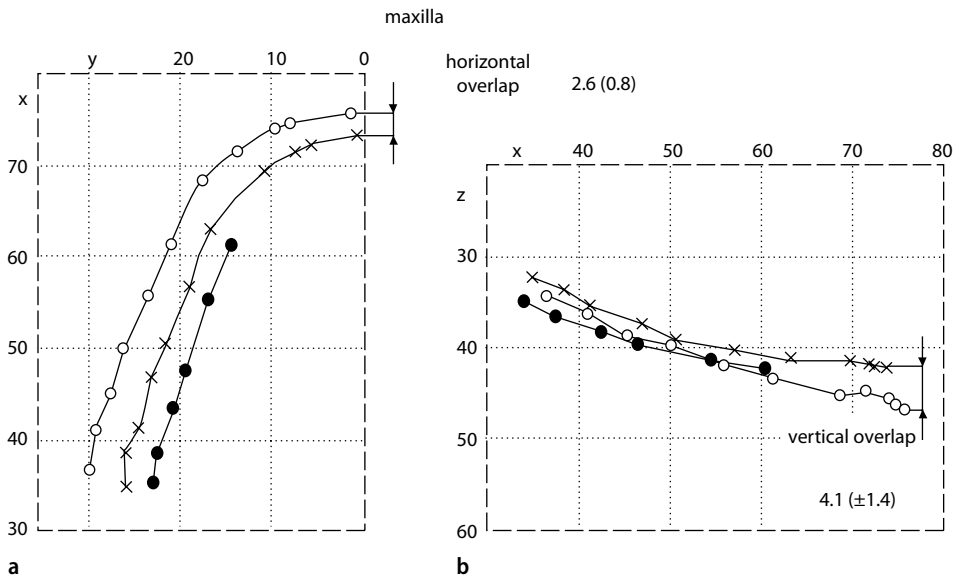

Fig. 6 **a**, Maxillary arch (*right side/half*): Projection of functional esthetic line (*open circles*), the line where mandibular incisal edges, the cusp of canine and buccal cusps of premolars and molars contact maxillary teeth (*crosses*) and the line of lingual cusp tips (*filled circles*) in x/y plane (AOP). **b**, Maxillary arch (*right side/half*): Projection of functional esthetic line (*open circles*), the line where mandibular incisal edges, cusp of the canine and buccal cusps of premolars and molars contact maxillary teeth (*crosses*) and the line of lingual cusp tips (*filled circles*) in x/z plane (*sagittal plane*). Lingual cusp tip of first premolar is shorter than buccal cusp tip, cusp tips of second premolar are approximately the same height and buccal cusp tips of molars are shorter than that of lingual molars. (measurements in mm)

Table 4 Mean width and (standard deviation mm) of occlusal table of premolars and molars in maxillary and mandibular arches

	Premolars	Molars	Difference	Percent
Maxillary arch	5.5 (0.3)	6.3 (0.4)	0.8 (0.4)	15% (8%)
Mandibular arch	4.6 (0.3)	5.7 (0.4)	1.0 (0.4)	23% (11%)

lingual cusp tips. The values measured in the maxillary teeth in total were greater than the values for the corresponding mandibular teeth. The occlusal table of the maxillary molars was 15% (±8.0%) wider than the corresponding premolars and that of the mandibular molars was 23% (±10.6%) wider than that of the corresponding premolars. There was no significant difference in occlusal table width between left and right side for the premolars and molars (Table 4).

Discussion

The distances of the mandibular buccal cusp tips to the occlusal plane and the radius and curve of Spee were confirmed in general. The only difference was that the cusp tip of the canine was 0.46 mm above the occlusal plane. The mean radius of the curve of Spee was found to be in the same range as described by Spee [1] 110 years ago, as well as that described by Orthlieb [8].

In the investigated sample the lateral incisors and the lingual cusp tips of the first premolars clearly did not reach the maxillary occlusal plane. It has been suggested that this prevents excessive load on the distal edges of the lateral incisors and prevents mediotrusive interferences on the lingual cusps of the first premolars during excentric mandibular movements [21]. With the exception of the mesiolingual cusp of the first molar no other molar cusp was in contact with the plate. This type of arrangement of the molars was described by Payne [22] as lingual contact occlusion and has been used for the tooth arrangement of complete dentures. The concept of lingualized occlusion as offered by Payne was suggested as a means of denture base stability over the basal seat of support for mandibular dentures but also contributes to avoid laterotrusive and mediotrusive molar contact.

Kulmer et al. [9] investigated the inclination of guiding elements in maxillary anterior and posterior teeth. The points of measurement for anterior teeth are shown in Fig. 2. For maxillary premolars and molars F1 is identical with the centric stop on the mesial marginal ridge and F2 is defined as the turning point of the mesial marginal ridge to the mesial cusp ridge of the buccal/mesiobuccal cusps. The authors concluded that due to this arrangement of the molars the inclination of the guiding elements F1–F2 to the AOP at the first molar measured 8.1° (±6.1°) and at the second molar 3.1° (±6.3°). Negative values for the possible guiding planes were found in 9% for the first and in 21% for the second molars. A closer look at the distances of the distobuccal cusp of the first maxillary molar reveals that this cusp tip was closer to the plate (0.72 mm) than the mesiobuccal cusp (0.81 mm). This can frequently be observed in natural dentitions. From the functional point of view of some authors [23, 24] this can result in a too steep inclination of the distobuccal cusp slope, consequently pathophysiological interferences at the working side may cause an increase of muscular activity during parafunction [23] and a distraction of the condyle from the eminentia articularis [24]. With a glass plate of adaequate size the situation can be evaluated any time not only on casts but also by intraoral chairside examinations.

The curve of Wilson (mediolateral curve) was found and confirmed for the maxillary and mandibular jaws as reported in the literature [3]. In clinical practice two problem areas are found that should be corrected in orthodontic treatment and avoided in prosthetic rehabilitation: (1) the extruded position of the distobuccal cusp of the first maxillary molar [11, 23] and (2) the lingualy tipped second mandibular molar [25]. In most situations the second mandibular molar has four cusps thus the distobuccal cusp may present a mediotrusive interference [20]. If the difference of buccal and lingual cusp height is as high as shown in this sample and there is such a pronounced concave curve of Wilson, serious problems may arise. In an 11-year follow-up of successfully treated complex patients, Kulmer [20] showed that the buccal and lingual cusps of the second molars were set nearly at the same height and destructive mediotrusive contacts were avoided successfully in the long term.

While it has been clear that the occlusal table in mandibular molars is wider than that of the premolars (23% in this sample), it has been reported that the width of the occlusal table is the same in maxillary premolars and molars. This study found the occlusal table of maxillary molars to be 15% wider than that of premolars.

The findings of this paper are limited to adolescents. Therefore, an investigation on a larger sample of adult patients could be recommended. Of great interest would also be an investigation on prosthetically treated patients shortly after rehabilitation and in a long-term follow-up.

Conclusions

Within the limitations of this study the following conclusions were drawn:

1. The anteroposterior curve (curve of Spee) and the mediolateral curve (curve of Wilson) as described in the literature were confirmed to be present in adolescent natural dentitions at the end of the tooth eruption period.
2. The occlusal plate rule as reported by Gysi could also be confirmed in these complete adolescent dentitions.
3. A 3D tooth arrangement as reported in this study allows a sufficient amount of vertical and horizontal overlap for anterior teeth and provides sufficient in-

terocclusal distance between the articulating surfaces of anterior teeth to disclude the cusps of premolars and molars during excentric mandibular movements.

Conflict of interest

The authors declare that there is no conflict of interest.

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