The angulation of upper 1\textsuperscript{st} permanent molars, the key to functional occlusion

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Background:

Occlusion and malocclusions in common orthodontics were defined in 1899 by the classification of Angle\textsuperscript{1,2}, the mesio-distal relationship of the crowns of first permanent molars. This classification of Angle was supplemented by the “Six Keys to Normal Occlusion” by Andrews\textsuperscript{3}, 1972, the findings of a basic research of 120 “ideal casts”. In orthodontic science intensive research was done for nearly any geometrical relationship of hard and soft tissue during growth and in adulthood, rarely in angulations of upper first permanent molars, being the prime landmarks for the classification of orthodontic malocclusions. In common orthodontics the measuring of head plates for diagnostic decision findings is focussing on the angulations of upper and lower centrals, rather than on those of the upper first molars, “the keys to occlusion”, Angle\textsuperscript{1,2}

By this general deficit, Andrews’ basic research of 120 “ideal casts” became the prime orientation for torques and angulations in orthodontic practice. On the other hand the doctrine of official anatomy gives precise definitions of “normal” teeth angulations and “torques” as well, Schumacher, G.H.\textsuperscript{4} They first had been introduced to orthodontic literature by the German Board of Orthodontists, COO, Risse\textsuperscript{5} in 2003 and on the 77\textsuperscript{th} Scientific Meeting of the German Society of Orthodontics, Freiburg, 2004: “The definition of the orthodontic treatment objective”, Risse, G.. They are unknown in common international orthodontics. The state of knowledge in the discipline of anatomy especially concerning the angulations of upper permanent canines and molars differs substantially from those in common orthodontics and those defined by Andrews. By this we have two opposing definitions defining “the rule of normal”. Both “rules of normal” are static definitions of adults for general orientation. “Age adapted angulation” is a new diagnostic and clinical view. The evaluation of age related angulations of upper first molars in scientific growth reports supports the dates of textbook-anatomy, which differ even more from common orthodontic prescriptions. Significant differences in upper first molar angulations lead to significant different eruption patterns of later erupting teeth and different functional patterns. However the most impressive deviation from “normal” orthodontic upper molar angulations is performed by treatment objectives with removable appliances by van der Linden, F.P.\textsuperscript{6}, supporting textbook-anatomy and “age adapted angulations” of Risse, G.\textsuperscript{5}

All available data lead to the conclusion, that prescriptions of upper molar angulations in common orthodontics (Key II, Andrews) may lead into a wrong direction. Opposing angulations of upper first permanent molars are leading to substantial different diagnostic evaluations and substantial different treatment procedures, different experiences and scientific evaluations/conclusions.

“First molars, the key to normal occlusion”, Angle’s argumentation

“All teeth are essential, yet in function and influence, some are of greater importance than others, the most important of all being the first permanent molars, especially the upper first molars, which we call the keys to occlusion.” Angle E.H.\textsuperscript{7}

“The most important teeth are the first permanent molars”. Angle’s argumentation for his postulation:
1. They are the biggest teeth and their anchorage is strongest.
2. Their local position in the occlusal arch supports the main masticatory duty and operation.
3. They influence the vertical distance of upper and lower jaws, the occlusal height and aesthetic proportions.
4. As the permanent molars are the first erupting teeth of permanent dentition, they have “mighty” control on the teeth erupting later behind and in front of them, as they are forced to position to the already erupted and in occlusion functioning 1\textsuperscript{st} molars.
5. As the permanent teeth of the lower jaw are erupting prior to the upper it is to resume, that the lower jaw is the form that defines and creates the form of the upper jaw.
6. The anomalies in dental positioning are mostly due to a more prominent dislocated position of the crowns of upper permanent molars to normal, less and minor due to a dislocation of their apex.
7. These findings lead Angle to postulate, “that the first upper permanent molar, more than any other tooth or anatomical point gives a precise scientific basis for defining occlusal disharmony and occlusal anomalies.”

Angle mentioned a greater stability of the dental apex of upper first molars in relation to the crown, already, meaning - angulation. Despite of this experience Angle defined occlusal anomalies by anterior – posterior relations of upper and lower first permanent molars, not in combination with angulations. This restricted view continued up to our days.

Angulations of upper first permanent molars are of prime diagnostic value as they define the positioning of later erupting teeth and by this a.o. anterior crowding, functional problems and diagnostic decisions, effectiveness, efficiency and stability.
Inclination of upper teeth from the vestibular viewing:
- the front teeth are inclined that way, that the gingival part is positioned distally in relation to their occlusal edge
- the first premolar is angulated perpendicular to the occlusal plane
- the gingival part of the long axis of posterior teeth in the upper jaw is positioned distally to the occlusal part of this axis.

"Key II states that the angulation of the facial axis of every clinical crown should be positive. The gingival part of the long axis of each crown in the upper jaw is positioned distally to the occlusal part of this axis."

A: An excessively concave curve of Spee and mandibular core line restrict the occlusal surfaces available for maxillary teeth.

B: A flat to slightly concave curve of Spee and mandibular core line bare the proper occlusal surfaces for optimal occlusion.

C: A convex curve of Spee and mandibular core line bare excessive portions of the occlusal surfaces.

Fig. 3 Curve of Spee, Andrews’ view. Fig. A and C has no relation to the sense of “Curve of Spee”.
Def. of Curve of Spee, textbook anatomy / G.H. Schumacher

“The curve of Spee is defined as that curve, which is connecting the edges and cusps of the upper teeth and is tangenting the distal part of the condyloyn.”

Def. of Compensation Curve, Dental Textbook, Lautenbach

“The compensation curve is defined by combining the upper and lower occlusal edges of upper and lower teeth, beginning in the front in form of a slightly downwards directed arch down to the anterior edge of the first molars, turning up posteriorly to the third molar. As to be seen, there is a more pronounced curvature posteriorly. - “Compensation curve in prostheses. By ignoring this curve the prosthesis would be displaced by a levering effect.”

In orthodontics a straightened curve of occlusion is causing levering effects in the TMJ with all possible consequences of destructions and “Costen-Syndrom”. Risse, G

The principle of Curve of Spee / Curve of Compensation by Textbook Anatomy; G.H. Schumacher

“The principle of the Curve of Spee / Curve of Compensation consists in getting a good position of occlusal surfaces of these teeth, against the main forcevector of masticatory muscles for a physiologic function.”

Comparison of functional occlusion between textbook anatomy 5a and 5b

- see the different angulations, the gross force direction of masticatory muscles in line with physiologic molar angulations, red: Andrews/textbook orthodontics.

Evolution / textbook anatomy (Schumacher)
The Curve of Spee and Curve of Compensation have their background in:
1. an evolutionary progress
2. a mechanical adaptation to mastication.
“Officials of the theory of evolution share the opinion, that the space-saving arch-forming positioning of teeth are resulting in the reduction of the mesio-distal depth of the jaws of human beings.” Jaws of primates as well as jaws of fossil hominids are excessively longer in comparison to human beings”. (G.-H. Schumacher)

The “Dynamic Key”, the “occlusion as a process” / interactive relations
The eruption of first permanent molars is finishing the deciduous dentition period.
From that point in time, after eruption of first permanent teeth, constant activation of the masticatory muscles and increased midface growth is observed. Spronsen\textsuperscript{10} et al. In the hypothesis of van Limborgh\textsuperscript{11} and in Moss’s\textsuperscript{12} hypothesis of the “Functional matrix” muscles and functional background play a prime role for craniofacial morphogenesis. Local factors such as masticatory muscles and tooth germ growth, their positioning during growth are considered to play the more important role in postnatal development and occlusion finding.

In this process three factors are important:

1. The factor of force amount
2. the reciprocal feedback
3. the factor of frequency of muscle activity and duration.

1) The masticatory muscle groups are the strongest in human organism, capable of producing a calculated force of up to 2,000 N/1 cm\textsuperscript{2}. The pressure on the teeth caused by masticatory muscles differs for different groups of teeth. By this, the pressure on molars is highest, lowest on the front teeth, Schumacher, G.H.\textsuperscript{4}

2) The increase in masticatory activity during reflex swallowing combined with an increase of occlusal pressure after eruption of first molars induces an adaptation in bone structure and bone statics by a feedback training of muscles by proper molar relations, Spronsen\textsuperscript{10}.

3) “Since reflex swallowing occurs so frequently, it acts as a dominant mechanism determining the tooth’s position”, Moyers, R.E.\textsuperscript{13} Lear et al\textsuperscript{14} reported that young adults swallowed an average range of 233–1008 and children an average range of 800 – 1200 per day. Position in combination with inclination of molars is working in a reciprocal support with and by muscle development in a positive stabilizing direction or in a destructive way for both parts. \textbf{Fig. 6/7}

The “Key Ridge” and upper molars

Angles defined the position of teeth by the key to occlusion. Atkinson 1951 defined the “Key Ridge”, the infrazygomatic crest. This key ridge in official anatomy is shown by Sicher, H., and du Brul, E. L.\textsuperscript{15} as pillar of trajectories. As to be seen in \textbf{Fig. 6c - f}, this zygomatic pillar – in orthodontics “key ridge” – is establishing during growth directly above the centre of the roots of the first upper molars and proceeds along the outside of the wall of the maxillary cavity up to the zygomatic bone.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig6abcdef.png}
\caption{Fig. 6c zygomatic pillar, Key ridge, starting from apex of \textsuperscript{1}st upper molar}
\end{figure}

This “key ridge” acts as a pillar on which the long axis of the roots of the first upper molar is resting. This bony background may be the reason for the greater stability of the apex of teeth, especially for upper molars at the end of growth and for differential anchorage. Is a first upper molar more angulated in relation to “normal”, the crown is positioned more mesially or more distally to this key ridge. By this unphysiologic loadings on the molars and the adjacent maxilla during action is the logical consequence, causing unphysiologic growth in any direction, open or deep bites, crowding and in general, orthodontic anomalies. \textbf{Fig. 6a,b,d,e,f, 7}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig6abcdef.png}
\caption{Fig. 6f: Demonstration of relative stable apices of all teeth with pronounced mesial inclination and resulting crowding for canines, developing key ridge from another perspective.}
\end{figure}
Fig. 7 Demonstration of masticatory force direction on mesial inclined upper first molar.

Recently FE models have confirmed the important influence of the upper 1st molar position in relation to the infrazygomatic crest and maxillary load transfer of bite forces by Gross M. D. et al16 and by Cattaneo, P. M., Dalstra M., Melsen, B.17

The 3 D FE analysis of Cattaneo et al demonstrated:
- “That a shift of a single cusp width (in relation to the infrazygomatic crest, “key ridge”) in the intramaxillary position of the molars in the mesio-distal direction has a significant impact on the occlusal load transfer.”
- “That the maxilla with the mesially displaced molars becomes more loaded in compression. The alveolar bone surrounding the teeth anterior to the infrazygomatic crest is, for a mesially displaced molar, in danger of overloading. This could cause local ischemia and lead to fenestrations and local dehiscences.”
- “That the load transfer for the model with the neutral molar position is optimal.”
- “Angle seems to have been right when he stated” the first upper molar can be considered the key to occlusion.”

The “Key of Age”, reevaluation of upper 1st molar drift, age related angulations

Björk and Skieller18 first visualized scientifically the facial development and tooth eruption by implants. These studies demonstrate the average drift of upper first molars, downwards and mesially. They show a continuously age related progressive change in angulation. All angulations show a prominent minus (-) angulation from −8° at the age of 11.8 down to −5° at the age of 17.9 years. Kim19 et al evaluated the shift of the occlusal plane from age 6 till adulthood. The evaluation of the angulations of upper molars in this study showed an average angulation of about −17° for children aged 6 to 7 years and −8° angulation at the age of 11 – 12 years similar to Björk’s18 drafts. Both studies show a general change in angulation of upper 1st permanent molars in relation to the mesial directed growth pattern from minus (-)17° down to −5° at the age of 18 years. By this, the term “age related angulations” may be postulated.

Facial development and tooth eruption – an implant study at the age of puberty. Björk/Skieller

Fig.9 Angulation at 11.8: −8°

Fig.10 Angulation at 14.8: −5°
Fig. 11 Angulation at $17^\circ$: $-5^\circ$.

Transition of molar relationships in different skeletal growth patterns. Kim et al.

Fig. 12a, Age 6, angulation $-17^\circ$.

Fig. 12b, Age 12, angulation $-8^\circ$.

Fig. 13a, Age 6, angulation $-17^\circ$.

Fig. 13b, Age 12, angulation $-7^\circ$.

Fig. 12a/b Measurements of upper molar angulations in the group in which maxillary sagittal growth was more than that of mandible, Kim et al.

Fig. 13a/b Measurements of upper molar angulations in the group in which mandibular sagittal growth was greater than that of maxilla, Kim et al.

Clinical consequences
Most treatments with fixed appliances and straight wire therapy are usually performed between the age of 10 and 16 years.
Assuming an average upper first permanent molar angulation of $-10^\circ$ for a ten years old patient, there will be a difference of $15^\circ$ between evidence based findings and the $+5^\circ$ angulation in common orthodontics / Andrews.
In applying straight-wire-techniques or uncontrolled levelling in a 12 years old patient, the roots of the 1\textsuperscript{st} upper molars will hardly go distally because of the position and pressure of the second and third molars in behind. Then the so called “row-boat-effect” happens, by which the crowns are swinging mesially. Assuming an average length of an upper first molar of 2 cm, a difference of $10^\circ$ in mesial angulation means a shift of the crown of 5 mm mesially, causing a. o. missing space anteriorly and occlusal changes. Unnecessary extractions are a frequent consequence.

Angulations and treatment objectives with removable appliances
Van der Linden\textsuperscript{6} evaluated his treatments with a special activator-headgear appliance – the “van Beek activator”. The results are a severe distal tipping of premolars and molars Fig 14a/b. Again the author didn’t provide data of
angulations. By re-evaluating the head plates and the draughts, van der Linden treated the angulations of upper first permanent molars up to $-21^\circ$ at an estimated age of 14 years. The head plates demonstrate significantly the relatively stable apex during treatment confirming Angle’s postulation 1906.

Fig. 14a van der Linden / van Beek. Treated case form beginning to end with a removable van Beek activator-headgear appliance form severe mesial angulations to striking distal angulations

Fig. 14b Measurement of upper molar of a treated case with a removable van Beek activator-headgear appliance, showing $-21^\circ$

Fig. 15 See different treatment goals with removable appliances (-21°), van der Linden (15a), in relation to fixed appliances (+5°) of upper first molars in common orthodontics, (15 b) .

Van der Linden\textsuperscript{6} concluded:
- Ninety percent of patients treated with a headgear-activator will reach a neutro-occlusion.
- Five years after treatment, only 50% of the headgear-activator patients have anterior guidance.
- 25% have an overjet of up to 4 mm, but that is not obvious and is not experienced as disturbing.
- However, 25% have a visible overjet, although it is always smaller than the overjet that existed prior to the treatment.
- Relapse occurs in all facial types and is primarily caused by deviating functional aspects in the orofacial region.
- Additional treatment with fixed appliances should not be started before the molars and premolars have improved their angulation; otherwise the disto-occlusion can return”. (row-boat-effect)

Discussion
Van der Linden\textsuperscript{6} defines “neutro-occlusion” anterior-posteriorly, excluding specification by angulations. The neutro-occlusion of Kl. I relationship in treatments with removable appliances was achieved in combination with an angulation of $-21^\circ$ of upper first molars. Common orthodontics / straight-wire-techniques define neutro-occlusion by an average angulation of upper molars by $+5^\circ$. Thus here are two worlds in anatomic definition with fundamental consequences for diagnosis, treatment objectives and functional loadings, skeletal and dental growth patterns as well as for “normal” TMJ-function.

The question is, which anatomic treatment objective should be defined for upper first permanent molar angulations?

Two opposing anatomic definitions for upper 1\textsuperscript{st} permanent molar angulations depending on the type of appliance used, is not acceptable. There are opposing rules. It makes a substantial difference to define a neutro-occlusion or Cl. I-occlusion of upper 1\textsuperscript{st} permanent molars by an angulation of $+5^\circ$, or $-21^\circ$ or $-5^\circ$, or age adapted.

Variations for 1\textsuperscript{st} upper molar angulations in Kl. I relation:
- with fixed appliances $+5^\circ$ angulation at any age,
with removable appliances -21° at the age of about 14 years,
textbook anatomy –5° for adults,
age adapted (related) angulations of –17° at the age of 6, continuously reducing with mesial growth drifts by age, down to –5° at 18 years.

Clinical experience with fixed appliances on the background of age adapted angulations, functional concepts for muscles and functional fixed mechanics are confirming high efficiency and effectivity, high stability, rare extractions and reduction of surgery. This will be demonstrated by a severe open bite case of an adult woman aged 23, changing (+) plus -angulations of upper 1st molars at the beginning, towards (-) minus –angulations, corresponding to official anatomic prescriptions at the end of treatment with fixed appliances. No surgery was needed. This case has remained stable for 10 years out of retention.

This direction of functional treatment by fixed appliances is called “New Orthodontics” or Bio-Functional Orthodontics, BFO, and needs new knowledge in systems engineering besides a new anatomic view. “Bio-mechanics” needs to be extended towards “bio-functional-mechanics”.

Fig.16a Beginning of treatment
Fig.16b End of treatment

Fig.17a Tracing of 16a
angulation of upper 1st molar: +13°

Fig.17b Tracing of 16 b
angulation of upper 1st molar: -6°

Fig.18a Superimposition in X
Fig.18b Superimposition in X
Conclusion

1. The overall significance of upper findings demonstrate a general angulation of upper first permanent molars of a minus (-) angulation to be a clear treatment goal. There is no significance for any plus (+) angulation for upper first permanent molars as a treatment goal during growth and rare evidence for adults.

2. The definition of Angle’s Kl. I relationship is the key to occlusion, but is insufficient for diagnosis and treatment procedures. It makes a great difference to define a neutral-occlusion by an angulation of upper first permanent molars with an angulation of +5°, -21°, -5°, or age adapted.

3. Timing of angulation of upper first permanent molars is a prime rule for physiologic loadings and for dental and skeletal growth patterns.

4. Active change and treatment of reflex swallowing is the Dynamic Key to “normal” and to a stable occlusion as a function-based occlusion.

5. Mesio-distal positioning combined with Age Adapted Angulations of upper first permanent molars are the keys for a functional occlusion.

6. Individual wire bending on “light wires” will support functional forces for individual occlusion finding.

7. Occlusion, especially in orthodontics during growth, is a process, a process of growing and shifting interactive systems. Orthodontics is navigation of systems. The upper first permanent molar seems to be the steering wheel.

8. Age adapted angulations of upper first permanent molars are a prime rule for diagnosis, treatment-planning, effectiveness, efficiency and stability.


Reference

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