TMJ internal derangement and adolescent craniofacial morphology: A pilot study

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Craniofacial morphology is the study of the dynamic relationships among various facial skeletal components during development. Numerous theories have been advanced to explain facial growth and development.[1-5] However, principles that apply to one area of facial growth may not apply to another. Mandibular development is no less complex, and in particular, controversy rages concerning the role of the condylar cartilage in development of the mandible. Mandibular development is of particular interest to the orthodontist in treatment planning. The effects of orthopedic forces on the condylar cartilage for growth modification are highly controversial. Researchers have suggested that condylar cartilage growth may be either stimulated or inhibited by the application of functional orthopedic appliances.[6-8] Others,[9,10] however, have been unable to show the effects of treatment on condylar cartilage, and they explain the facial changes accompanying these therapies as being mainly dentoalveolar compensations.

In vitro animal[11-13] and human fetal[14] studies have shown little intrinsic growth potential of secondary condylar cartilage compared with primary cartilage from epiphyseal plates. Petrovic and Stutzmann[5] argued that the functional environment and action of the lateral

Abstract

Intrinsic and extrinsic factors influence the growth of mandibular condylar cartilage. Local environmental factors, such as temporomandibular disc displacement, may alter condylar cartilage growth resulting in facial changes. The aim of this study was to determine if there was an association between identifiably altered craniofacial morphology and disc displacement. Magnetic resonance imaging (MRI) was employed to determine disc position in 25 preorthodontic adolescent patients (mean age 12.8 years, range 10 to 17 years). Magnetic resonance imaging and lateral cephalometric radiography were performed with the teeth held in centric occlusion by means of a polyvinylsiloxane bite registration. Radiographs were traced and variability between tracings within patients was insignificant for all variables ($p > 0.04$) except Co-Go, S-Go, and SN/Go-Me ($p < 0.01$). For each patient, 10 linear, 4 angular, and 3 ratio measurements were compared with an age- and sex-matched population in the Craniofacial Growth Series. Multiple regression analysis showed positive and negative associations between disc displacement and cephalometric variables. R-square value was .91 for the left TMJ and .82 for the right. Disc displacement in an adolescent population may be associated with altered craniofacial morphology.

Key Words

TMJ internal derangement • Magnetic resonance imaging • Craniofacial morphology

Submitted: April 1996 **Revised and accepted:** October 1996 Angle Orthod 1997;67(6):407-414.

Table 1
Study population

	Males	Females
Total number	5	20
Mean age (years)	12.6	12.9
Age range (years)	11 - 15	10 - 17

Table 2
Cephalometric landmarks and planes

S	Sella–center of pituitary fossa of sphenoid bone as identified by visual inspection
N	Nasion–junction of frontonasal suture at most posterior point on curve at the bridge of the nose
ANS	Anterior nasal spine–tip of median bony process of the maxilla at lower margin of anterior nasal opening
ANS'	A point on upper contour of ANS where vertical thickness is 3 mm
ANS"	A point on lower contour of ANS spine where vertical thickness is 3 mm
PNS	Posterior nasal spine–most posterior projection of bony contour of palate
Co	Condylion–most posterosuperior point on bony outline of the average right and left condylar head
Go	Gonion–most posteroinferior point on bony angle of average left and right mandibular outlines
Me	Menton–most inferior point on bony outline of mandibular symphysis in midsagittal plane
Ar	Articulare–intersection of inferior cranial base surface and the averaged posterior surfaces of the mandibular condyles
ANS-PNS	Palatal plane–plane formed by connecting ANS and PNS
SN	Sella-nasion–plane formed by connecting S and N
OP	Functional occlusal plane–A plane drawn through points of contact between the first permanent molar and first and second premolars (or of deciduous molars)
Go - Me	Mandibular plane–plane formed by connecting Go and Me

pterygoid muscle are important in the development of condylar cartilage and, hence, the mandible. Independently, this led Copray et al.[15] to conclude that local environmental factors are of importance in considering condylar growth.

Dolwick[16] defined internal derangement of the temporomandibular joint (TMJ) as the "abnormal relationship of the articular disc to the condyle, fossa, and articular eminence, with the disc usually displaced in an anteromedial direction." Since disc displacement can be seen as a loss of harmony between functional TMJ components, it may be considered a local environmental disturbance with the potential to affect condylar development.

Juvenile rheumatoid arthritis has been shown to have a profound effect on craniofacial growth, presumably by inflammatory destruction of the condylar cartilage.[17-19] Altered condylar morphology or loss of normal shape, as seen on plain film radiography, has been associated with altered craniofacial morphology, although no clear cause-and-effect mechanism was postulated.[20] Patients with disc displacement without reduction show osseous changes of the condylar head, but these changes are found less frequently in patients with disc displacement with reduction.[21-22] A strong relationship between disc perforation and degenerative joint disease of the temporomandibular joints has been shown, whereas the relationship between internal derangement and degenerative joint disease is less evident.[23]

Internal derangement represents a less "violent" change in the local environment. Nevertheless, disc displacement "pulls" the retrodiscal tissue forward between the condyle and articular eminence, with potentially harmful effects. Compression of this normally vascular tissue may occur, altering oxygenation, nutrition, and lubrication of condylar tissue through synovial fluid changes. These localized changes may be adequate to alter the dynamic growth within this region, resulting in a loss of facial growth equilibrium expressed in the various adaptive growth sites. The aim of this study was to determine whether temporomandibular disc displacement is associated with specific craniofacial characteristics.

Materials and methods

A pilot study was conducted on individuals drawn from an orthodontic practice prior to appliance placement. Thirty-two individuals volunteered for inclusion; seven were excluded due to poor quality MRIs or cephalometric ra-

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Table 3
Linear cephalometric measurements

N-ANS'	Anterior upper facial height (AUFH)
ANS'-Me	Anterior lower facial height (ALFH)
N-Me	Anterior total facial height (ATFH)
Co-Go	Ramus height (RH)
OP-(ANS-PNS)	Perpendicular distance from mesiobuccal cusp tip of maxillary first molar to palatal plane (6-PP)
Go-Me	Mandibular corpus length (CL)
Co-ANS"	Anteroposterior maxillary length (Max)
Co-Me	Anteroposterior mandibular length (Mnd)
S-Go	Total posterior face height (TPFH)
(ANS-PNS)-SN (perp to SN)	A perpendicular from SN to PNS at point of intersection with inferior of pterygomaxillary fissure (PUFH)

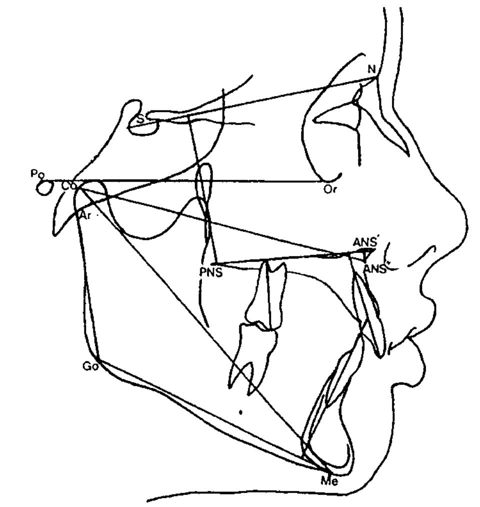

Figure 1

Figure 1
Cephalometric landmarks

diographs. The sample included both males and females, with an age range of 10 to 17 years, and a mean age of 12.8 years (Table 1). The group included some individuals with clinically detectable TMJ symptoms (capsular pain, joint sounds, masticatory muscle tenderness, limited mandibular range of motion, deviation on opening) and some who were free of symptoms.

Closed-mouth lateral cephalometric radiographs were obtained using a polyvinylsiloxane (President Jet-Bite, Coltene/Whaledent Inc, Mahwah, NJ) centric occlusion bite registration. Open-mouth lateral cephalometric radiographs were exposed to accurately determine the shape of the condylar head. A left hand-wrist radiograph was produced to determine skeletal age of the individual, using Greulich and Pyle's[24] skeletal maturity indicators. All radiographs were made on a Siemens OP10 radiographic machine.

Lateral cephalometric radiographs were traced on acetate tracing film by a single investigator (BN). An accurate outline of the condylar head was obtained by superimposing the closed mouth tracing of the symphysis, the lower border of mandible, developing dental follicles and the enamel organ (where present) on the open-mouth image. Cephalometric landmarks are illustrated in Figure 1 and defined in Table 2. Cephalomeric measurements, angles, and ratios are presented in Tables 3 to 5. Linear measurements were made with a Mitutoyo digital caliper accurate to 0.01 mm (Mitutoyo Canada Inc, Mississauga, Ontario). Angular measurements were determined using a protractor accurate to 1 degree. Each subject was age- and sex-matched to population norms presented in the Craniofacial Growth Series.[25] Maxillary unit lengths (Co-ANS") were not matched to the Craniofacial Growth Series data but to data presented by McNamara.[26]

Magnetic resonance imaging of the TMJs were performed on the same day as the radiographic evaluation. Imaging was completed without sedation using a 1.0 T magnet (Shimadzu Corporation 3, Kanda-Nishikicho 1-chrome, Chiyoda-Ku, Tokyo 101, Japan) and a unilateral 3-inch surface receiver coil. Axial scout images were obtained to identify the condyles. Bilateral closed-mouth parasagittal sections were obtained using the same bite registration employed for closed-mouth lateral cephalometric radiography. Bilateral open-mouth parasagittal images were produced using a Burnett caliper (Medrad, Pittsburgh, Penn) set at 10 mm below the maximal voluntary interincisal mouth opening. T1-weighted 500/20 (TR ms/ TE ms) pulse sequences were performed on all subjects using a 3-mm slice thickness, 140-mm field of view, NEX of 2, and an image matrix of 204 x 204. A radiologist with expertise in interpretation of TMJ MRIs traced the articular structures and the posterior band of the articular disc on all parasagittal MRIs.

Disc position was evaluated in accordance

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Figure 2
Determination of disc position (Drace & Enzmann 1990)

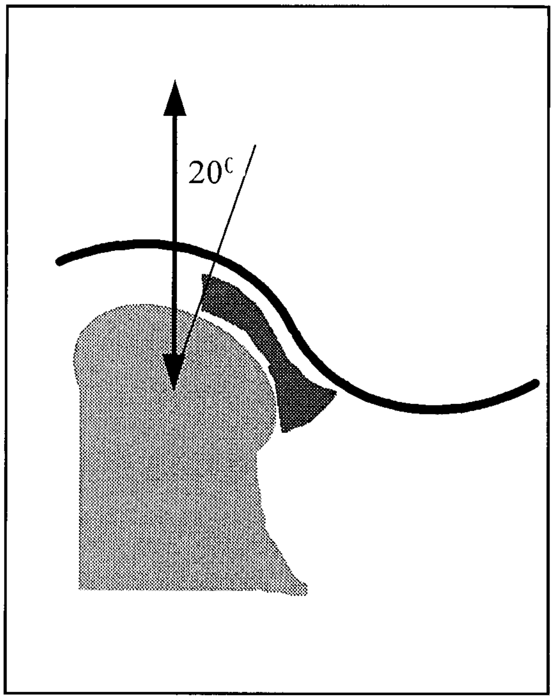

Figure 2

with the principles of Drace and Enzmann.[27] The disc was considered to be in a normal relation to the articular structures, in the closed mouth position, when the posterior band (junction of the posterior band and bilaminar zone) of the disc was within ±10 degrees of the 12 o'clock position of the head of the condyle. Disc displacement was measured as the anterior or posterior angular deflection of the posterior band of the disc from the 12 o'clock position (Figure 2).

Statistical evaluation

Ten radiographs were randomly selected and traced on five separate days by the same investigator (BN) to determine reproducibility of landmark identification and measurement technique. A one-way random effects model, with radiographs as factors and tracings as nested effects within the factors, was used to determine the intraclass correlation coefficient. Based on this model, independent cephalometric variables were tested using a univariate F-test. Variability between tracings within patients was insignificant for all variables ($p>0.04$) except for Co-Go, S-Go, and SN/Go - Me ($p<0.01$). Standard error of the mean (SEM) for each variable was computed using the within-patient variability in tracing and ignoring the between-patient variability of each independant variable (Table 6).

For each patient, 10 linear, 4 angular, and 3 ratio measurements were compared with an age-and-sex-matched "standard population" from the Craniofacial Growth Series.[25] A stepwise multiple regression analysis was used to determine the relationship between angular disc displacement and cephalometric variables.

Independent variables were obtained from the lateral cephalometric radiographs and were defined as:

$$\frac{CV^{S} - CV^{STD}}{SD^{STD}} = \text{standardized score}$$

that is, the cephalometric variable for the subjects (CV^S) minus the mean of the cephalometric variable for the standard population (CV^{STD}), divided by the standard deviation of the cephalometric variable for the standard population (SD^{STD}) generated a standardized score that was used as the independent variable.

Sine transformations of the angular displacement of the posterior band of the disc from the 12 o'clock position, obtained from MRI interpretation, were used as the dependent variables. Analyses were computed using an S-Plus statistical package. The difference in magnification factor of radiographs in the current study and that obtained in the Craniofacial Growth Series was not factored into the analysis, as this was calculated to be only 1.08%.

Results

Results of a stepwise multiple regression analysis are provided in Table 7 together with *p*-values and regression coefficients. Variables with p-values < 0.05 were not deleted from the model, as this would have resulted in a significant loss of information in predicting the responses (left TMJ/right TMJ). Stepwise multiple regression analysis showed a positive association between angular transformation measurements of disc displacement and maxillary length, mandibular plane, and SN to palatal plane, and a negative association between disc displacement and vertical ramus height, posterior facial height, posterior to anterior facial height ratio, and maxillary molar height to palatal plane. R-square values for seven variables were .91 for the left TMJ and .82 for the right.

Discussion

In planning treatment for adolescents, the orthodontist is aware that facial growth may be altered by manipulation of three adaptive growth sites: the maxillary sutural system, the dentoalveolus, and the condyle of the mandible. Orthopedic and orthodontic forces have been

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Table 4
Angular cephalometric measurements

SN/Go-Me	Mandibular plane angle (MP)
Ar-Go-Me	Gonial angle (AGM)
SN/PNS-ANS	Palatal plane angle (SN-PP)
Interincisal angle	Interincisal angle (INC)

Table 5
Ratios of linear cephalometric measurements

S-Go : N-Me	Total posterior facial height to anterior total facial height (TPFH:ATFH)
N-ANS' : ANS'-Me	Anterior upper facial height to anterior lower facial height (AUFH:ALFH)
ANS'-Me : N-Me	Anterior lower facial height to anterior total facial height (ALFH:ATFH)

Table 6
Reproducibility of landmark identification

Independent variables	SE Mean *
ANS'-Me	0.409988
OP-(ANS - PNS)	0.430488
SN/Go-Me	0.517204
(ANS - PNS) - SN	0.517793
S-Go	0.551435
Ar-Go-Me	0.578792
N-ANS'	0.597244
N-Me	0.600941
SN/PNS-ANS	0.602080
Co-Me	0.603573
Interincisal angle	0.817007
Co-ANS"	0.898838
Co-Go	0.921450

*Degrees of freedom associated with SEM values are 40

Table 7
Multiple regression analysis results based on 25 subjects

Independent variable	Dependent variable	Regression coefficient
Left TMJ		
Co - ANS"	positive association (p=0.03)	0.081576
S-N / Go - Me	positive association (p=0.02)	0.239062
SN - (ANS - PNS)	positive association (p=0.0003)	1.37304
TPFH: ATFH ratio	negative association (p=0.0002)	-1.3978
OP - (ANS - PNS)	negative association (p=0.043)	-0.09234
Co - Go	negative association (p=0.0001)	-0.142356
S - Go	negative association (p=0.003)	-0.9873
R^2 value	.91	
Right TMJ		
Co - ANS"	positive association (p=0.002)	0.286513
S-N / Go - Me	positive association (p=0.009)	0.433316
SN - (ANS - PNS)	positive association (p=0.0018)	0.78345
TPFH: ATFH ratio	negative association (p=0.0013)	-0.912035
OP - (ANS - PNS)	negative association (p=0.0012)	-0.978231
Co - Go	negative association (p=0.0015)	-0.822341
S - Go	negative association (p=0.0001)	-1.34567
R^2 value	.82	

applied to the maxillary sutural system and the dentoalveolus with great success, but manipulation of condylar cartilage growth has been less predictable. This has possibly resulted in practitioners shying away from treatment involving the mandibular condyle as an important adaptive growth site with potential for influencing craniofacial morphology.

In the adult population, the pathogenesis of degenerative joint disease has been linked to internal derangement.[22,28] Facial patterns accompanying internal derangement in the adult patient were noted by Link and Nickerson[29] in an adult surgical sample. Björk[30] presented the gross morphological alterations that may be expected in the craniofacial region when there is a total lack of condylar cartilage growth contributing to mandibular development and facial growth in the growing individual. These articles serve to illustrate identified associations between altered craniofacial morphology and localized TMJ disturbances.

Stegenga et al.[31] argued that internal derangement alters the physical properties of the TMJ and affects its ability to withstand compressive and shearing forces. Increased friction between the articular surfaces may impair joint movement and may elicit pathologic responses of the cartilage and adjacent tissues, such as subchondral bone and associated musculature. This being the case, the adaptive growth response of condylar cartilage may be affected. An alteration in TMJ and related muscle function may further inhibit condylar development. Growth alterations may be detected in the developing craniofacial structures, and in particular the mandible of the adolescent.

The findings of the current study tend to support the argument that internal derangement may be associated with altered craniofacial morphology in an adolescent sample. This pilot study shows reductions in total posterior

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facial height development and ramus height and a compensatory adaptation in the maxillary dentoalveolar region with reduced vertical development of the maxillary first molar region. These craniofacial alterations occur in the presence of internal derangement in the left and/or right TMJ. In association with a lack of posterior facial height development, a compensatory clockwise rotation of the palatal plane and the mandibular plane relative to sella-nasion was recorded. From this pilot study it appears that maxillary growth was expressed in a more anterior direction due to limitations imposed on its vertical development by the relatively mature cranial base posterosuperiorly, and reduced vertical mandibular growth posteroinferiorly.

These results are preliminary, obtained from a small sample. The explained variance presented in Table 6 is possibly higher than expected due to the small sample size relative to the number of independent variables analyzed. A more complete study with a larger sample and a control group is necessary to evaluate TMJ internal derangement in the adolescent population. Furthermore, this study represented a cross-sectional evaluation; at present, no longitudinal data involving MRI assessment of disc position are available to support the concept of growth alteration that may be occurring. This should in no way diminish our responsibility to identify internal derangements in the adolescent population and to further our understanding of the sequelae of the disorder.

Conclusions

The results of this pilot study indicate that internal derangement in the adolescent population may be associated with certain craniofacial features:

1. Reduced ramus and total posterior facial heights compared with norms.

2. Dentoalveolar adaptation in the posterior maxillary region, with reduced maxillary molar to palatal plane height.

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3. Increased palatal plane and mandibular plane angles relative to sella-nasion.

4. Increased degree of disc displacement, positively associated with increased maxillary anteroposterior dimension.

Acknowledgments

This study was supported by The Magnetic Resonance Center of Edmonton Inc, Edmonton Diagnostic Imaging Inc, and the Raburn McIntyre Fund.

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