Is it Possible to Modulate the Growth of the Human Mandible with a Functional Appliance?

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Summary
A significant increase in overall mandibular length can be achieved with a functional appliance. However, this only appears possible in children with a high tissue-level growth potential and responsiveness as defined by the mandibular subperiosteal ossification rate and alveolar bone turnover rate.

The problem of whether the growth of the human mandible can be modulated by orthopedic or functional appliances remains controversial. It would be impossible in this short presentation to review past investigations. Only our recent experimental and clinical studies will be reported.

Extensive research studies in rat (Petrovic and Charlier, 1967; Charlier et al., 1969; Petrovic et al. 1975; Petrovic et al., 1981; Petrovic, 1982; Petrovic, 1984); and in monkey (Stocki and Willert, 1971; McNamara, 1977; Komposch and Hockenjos, 1977; Graber, 1977; Carlson et al., 1978; McNamara et al., 1982; Graber, 1983) have demonstrated beyond reasonable doubt that APPROPRIATE functional or orthopedic appliances may stimulate or restrain the growth rate and growth amount of the condylar cartilage and of the posterior border of the ramus.

Are these experimental findings applicable to humans?

FIRST, it is well known that the responsiveness of different children to functional appliances is very variable. Our biologic concept of mandibular tissue-level growth potential and responsiveness to orthopedic and functional appliances, as based on investigations on human mandibular tissues, is an attempt to account for interindividual differences that the clinician is facing in his daily practice (Petrovic and Stutzmann, 1986). Comparative studies on the human ramus subperiosteal ossification rate, on the alveolar bone turnover rate and its orthodontically induced variations, and on the clinical effectiveness of the LSU-activator, Fraenkel appliance, Begg technique and Edgewise show that biological features of mandibular tissues, and especially the level of the tissue growth potential and responsiveness, are essential for clinical responsiveness (Petrovic and Stutzmann, 1984, 1986).

SECOND, our research investigations at the tissue, cell and molecular level have established, in organ culture, that the responsiveness of various human growth cartilages to appropriate biomechanical factors does NOT differ significantly from the CORRESPONDING animal growth cartilages (Petrovic, 1982; Petrovic, 1984; Petrovic and Stutzmann, 1986).

For instance, appropriate pressure in organ culture, on the growing condylar cartilage originating from children and from laboratory animals (rat, mouse, guinea pig, rabbit, squirrel monkey) systematically induces the following variations in the cell-division compartment (Petrovic, 1982, 1984; Petrovic and Stutzmann, 1987):
- cytosolic (Na) decreases; cytosolic (Ca) and (H) increases; intracellular water content increases; intracellular pH decreases;
- the number of cell divisions decreases.

Such variations were NOT detected when primary cartilages (epiphyseal growth plate of long bones, metatarsal and metacarpal cartilages, etc.) originating from children and from the same laboratory animals were exposed in culture to SIMILAR pressure. These research investigations show how the biologic features of mandibular tissues account for the HETEROGENEITY in the responsiveness of children to appliance therapy. These studies clearly demonstrate that, biologically, there is no reason to state that the human mandible should react differently from the animal mandible to similar appliances.

Our studies also show how a new classification of facial growth rotations is a useful tool in detecting, INDIRECTLY, the responsiveness level of a growing child to various appliances (Lavergne, Petrovic, 1985; Petrovic et al., 1986). According to this biologic and cephalometric classification, there are 6 growth categories and 11 rotational types (Fig. 2 and 3a, 3b, 3c).

The results of long term investigations with appropriate functional appliance show that a moderate increase in overall mandibular length may be achieved in rat (Petrovic et al., 1981) and in monkey (McNamara, 1986).

And in humans?
The answer is a difficult one. No research approach is faultless. We are using the following procedure (Fig. 1). In 9 to 12 year-old boys with a skeletal Class II, 4 cephalographs were made at about 6-month intervals. The children were classified according to the growth category and to the rotational type (Lavergne, Petrovic, 1985; Petrovic et al., 1986). The supplementary lengthening of the distance between condylion and pogonion observed in boys (Fig. 3a, 3b, 3c) treated with the LSU-activator (Shaye et al., 1979; Shaye, et al., 1979; Shaye, 1983) was compared to the supplementary lengthening observed in nontreated boys (Fig. 2) i.e. to the lengthening due to puberal physiological variations (the "control group" is later treated with Edgewise). The difference between the 2 groups is considered as induced by the LSU-activator. The LSU-activator group and the control group were
**Skeletal Growth**

Prepubertal and pubertal acceleration

**Skeletal Age**

<table>
<thead>
<tr>
<th>Bjork's P2</th>
<th>Sesamoid mineralization</th>
<th>Pubertal growth peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st premolar</td>
<td>1st premolar</td>
<td>2nd premolar</td>
</tr>
</tbody>
</table>

-6 to 0 months  | 0 to 6 months  | 6 to 12 months  |

**Cephalograph**

<table>
<thead>
<tr>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Controls</th>
<th>(Cp0)</th>
<th>(Cp1)</th>
<th>(Cp2)</th>
<th>(Rp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control period</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Initial treatment period</td>
<td>(ITp)</td>
<td>(ITp)</td>
<td>(ITp)</td>
<td>(ITp)</td>
</tr>
<tr>
<td>Subsequent treatment period</td>
<td>(STp)</td>
<td>(STp)</td>
<td>(STp)</td>
<td>(STp)</td>
</tr>
<tr>
<td>Final treatment period</td>
<td>(FTp)</td>
<td>(FTp)</td>
<td>(FTp)</td>
<td>(FTp)</td>
</tr>
</tbody>
</table>

**Fig. 1.** Timing of the 4 cephalographs and SL. 1. Taiming 4 ketalograma i tretiranja of the LSU-activator treatment. LSU-aktivatorom.

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**Fig. 2.** Mandibular lengthening in 9 to 12 year-old non-treated boys matched by clinical features and skeletal age with LSU-activator-treated boys (Median value for each rotational type).

<table>
<thead>
<tr>
<th>Sc</th>
<th>R</th>
<th>X</th>
<th>Control period (Cp0)</th>
<th>Control period (Cp1)</th>
<th>Control period (Cp2)</th>
<th>Corresponding to</th>
<th>Corresponding to</th>
<th>Corresponding to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-6 to 0 months</td>
<td>0 to 6 months</td>
<td>6 months to 12 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lengthening</td>
<td>Lengthening</td>
<td>Lengthening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cp0 - Cp1</td>
<td>Cp1 - Cp2</td>
<td>Cp2 - Cp0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>P20</td>
<td>9</td>
<td>0.29 mm (0.21 - 0.45)</td>
<td>0.47 mm (0.29 - 0.58)</td>
<td>0.68 mm (0.66 - 0.79)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A20</td>
<td>13</td>
<td>0.46 mm (0.45 - 0.58)</td>
<td>0.76 mm (0.48 - 0.64)</td>
<td>0.99 mm (0.66 - 1.14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A20</td>
<td>17</td>
<td>0.57 mm (0.54 - 0.64)</td>
<td>0.99 mm (0.95 - 0.99)</td>
<td>1.18 mm (1.10 - 1.35)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A1M</td>
<td>9</td>
<td>0.54 mm (0.49 - 0.64)</td>
<td>0.90 mm (0.72 - 1.09)</td>
<td>1.27 mm (1.10 - 1.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A20</td>
<td>17</td>
<td>0.54 mm (0.38 - 0.58)</td>
<td>1.34 mm (1.03 - 1.67)</td>
<td>1.68 mm (1.38 - 1.98)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A1M</td>
<td>21</td>
<td>0.74 mm (0.61 - 0.84)</td>
<td>1.19 mm (0.94 - 1.33)</td>
<td>1.91 mm (1.64 - 2.20)</td>
<td></td>
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</tbody>
</table>
Fig. 3a. LSU-activator-induced supplementary lengthening of the human mandible in 9 to 12 year-old growing boys (median value for each rotational type).

<table>
<thead>
<tr>
<th>Gc</th>
<th>Rt</th>
<th>Reference period (Rp)</th>
<th>Initial Treatment period (ITp)</th>
<th>Subsequent Treatment period (STp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6 to 6 months</td>
<td>0 to 6 months</td>
<td>6 months to 12 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Lengthening</th>
<th>Lengthening</th>
<th>Lengthening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Rp - Rp) mm</td>
<td>(ITp - Rp) mm</td>
<td>(STp - Rp) mm</td>
</tr>
<tr>
<td>1</td>
<td>P20</td>
<td>0.37 ± 0.06</td>
<td>0.84 ± 0.06</td>
<td>0.47 ± 0.06</td>
</tr>
<tr>
<td>2</td>
<td>A20</td>
<td>0.49 ± 0.06</td>
<td>1.63 ± 0.06</td>
<td>1.14 ± 0.06</td>
</tr>
<tr>
<td>3</td>
<td>R20</td>
<td>0.55 ± 0.06</td>
<td>1.71 ± 0.06</td>
<td>1.16 ± 0.06</td>
</tr>
<tr>
<td>4</td>
<td>R10</td>
<td>0.58 ± 0.06</td>
<td>1.88 ± 0.06</td>
<td>1.30 ± 0.06</td>
</tr>
<tr>
<td>5</td>
<td>A10</td>
<td>0.70 ± 0.06</td>
<td>3.36 ± 0.06</td>
<td>2.66 ± 0.06</td>
</tr>
<tr>
<td>6</td>
<td>R10</td>
<td>0.79 ± 0.06</td>
<td>3.62 ± 0.06</td>
<td>2.85 ± 0.06</td>
</tr>
</tbody>
</table>

Gc : Growth category.
Rt : Rotational type.
The lengthening was measured between condyion and pogonion.
The supplementary lengthening, during the initial and the subsequent treatment period, was calculated by comparison with the reference period.
The vertical relation was normal.

Fig. 3b. LSU-activator-induced supplementary lengthening of the human mandible (9 to 12 year-old growing boys).

<table>
<thead>
<tr>
<th>Gc</th>
<th>Rt</th>
<th>(ITp - Rp)</th>
<th>(Cp1 - Cp0)</th>
<th>S1</th>
<th>(STp - Rp)</th>
<th>(Cp2 - Cp0)</th>
<th>S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P20</td>
<td>(+ 0.47 mm)</td>
<td>(+ 0.08 mm)</td>
<td>+ 0.39 mm</td>
<td>(+ 0.70 mm)</td>
<td>(+ 0.29 mm)</td>
<td>+ 0.41 mm</td>
</tr>
<tr>
<td>2</td>
<td>A20</td>
<td>(+ 1.14 mm)</td>
<td>(+ 0.28 mm)</td>
<td>+ 0.86 mm</td>
<td>(+ 1.19 mm)</td>
<td>(+ 0.51 mm)</td>
<td>+ 0.68 mm</td>
</tr>
<tr>
<td>3</td>
<td>R20</td>
<td>(+ 1.16 mm)</td>
<td>(+ 0.37 mm)</td>
<td>+ 0.79 mm</td>
<td>(+ 1.30 mm)</td>
<td>(+ 0.58 mm)</td>
<td>+ 0.72 mm</td>
</tr>
<tr>
<td>4</td>
<td>R10</td>
<td>(+ 1.30 mm)</td>
<td>(+ 0.35 mm)</td>
<td>+ 0.95 mm</td>
<td>(+ 1.65 mm)</td>
<td>(+ 0.70 mm)</td>
<td>+ 0.95 mm</td>
</tr>
<tr>
<td>5</td>
<td>A10</td>
<td>(+ 2.66 mm)</td>
<td>(+ 0.58 mm)</td>
<td>+ 2.08 mm</td>
<td>(+ 3.24 mm)</td>
<td>(+ 1.02 mm)</td>
<td>+ 2.22 mm</td>
</tr>
<tr>
<td>6</td>
<td>A10</td>
<td>(+ 2.83 mm)</td>
<td>(+ 0.95 mm)</td>
<td>+ 1.98 mm</td>
<td>(+ 3.77 mm)</td>
<td>(+ 1.17 mm)</td>
<td>+ 2.60 mm</td>
</tr>
</tbody>
</table>

Gc : Growth category.
Rt : Rotational type.
Cp0 : Control period corresponding to the Reference period (Rp).
Cp1 : Control period corresponding to the Initial Treatment period (ITp).
Cp2 : Control period corresponding to the Subsequent Treatment period (STp).
S1 : Supplementary lengthening.
Identification of the positional rotation group

PATIENT: 11 year-old boy

- measured SNB = 72.5  (retrognathic mandible)
- measured SNA = 78.5  (orthognathic maxilla)
- measured ML/NSL = 34.0
- measured NL/NSL = 9.0

- expected ML/NSL = 192 - 2 (measured SNB)
  = 192 - 2 (72.5) = 192 - 145 = 47.0

- expected NL/NSL = (measured ML/NSL)/2 - 7
  = 34/2 - 7 = 10.0

- \( T1 = \) expected ML/NSL - measured ML/NSL = 47.0 - 34.0 = 13.0
  Anterior inclination of the mandible.

- \( T2 = \) expected NL/NSL - measured NL/NSL = 10.0 - 9.0 = 1.0
  Neutral inclination of the maxilla.

- \( T3 = \) measured ANB
  = ANB = SNA - SNB = 78.5 - 72.5 = 6
  Distal basal interjaw relationship.

ROTATION GROUP = A1DN

Clinical effectiveness of one year
LSU-Activator treatment: ++ +
IDENTIFICATION OF THE POSITIONAL GROWTH ROTATION GROUP
(according to PETROVIC, STUTZMANN, LAVERGNE, 1990)

ML : Mandibular line, the line tangent to lower border of mandible through gnathion
NSL : Nasion-sella line, the line through N and S
NL : Nasal line, the line through ANS and PNS
(ANS : anterior nasal spine, PNS : posterior nasal spine)
ML/NSL : Angle between mandibular line and nasion-sella line
NL/NSL : Angle between nasal line and nasion-sella line

T₁ = Expected ML/NSL - Measured ML/NSL
T₂ = Expected NL/NSL - Measured NL/NSL
T₃ = Measured ANB

Expected ML/NSL = 192 - 2(Measured SNB)
Expected NL/NSL = (Measured ML/NSL)/2 - 7

--- Diagram ---

T₁ > 6

T₂ ≤ 0

T₂ > 0

T₁ ≤ 6

--- Decision Points ---

T₁ < 0

T₂ > 0

T₂ ≤ 0
matched by statural growth increment, skeletal age, to some extent by tooth emergence, and especially by the lengthening of the mandible during the reference period (Rp) vs the control period (Cpo).

It appears that the actual supplementary lengthening of the mandible induced by the LSU-activator (S11 and S12), depends mainly on the tissue-level growth category (Fig. 5a, 3b, 3c). Only in the growth category No 5 (rotational types A1D and A1N) is the actual one-year lengthening clinically really significant (4.30 mm and 4.56 mm after a one-year treatment). However the result in growth category No 2 (rotational type A2D) is not negligible.

The reported clinical findings are to be compared with previously published biological findings (see: Fig. 7.4 and Table 7-7 in, Petrovic et al., 1985).

In conclusion, the results of this clinical investigation seem to indicate that a significant increase in overall mandibular length is achievable with a functional appliance, especially in growth category No 5. In other words, a methodologically rigorous evaluation of the modus operandi of a functional appliance has to take into account the biloigico HETEROGENEITY of the human mandibular tissues. The reported results fit with our previous investigations (Petrovic and Stutzmann, 1986) furnishing evidence that there is, in a growing individual, a remarkable parallelism between the variations in the subperiosteal ossification rate, the variations in the condylar cartilage growth rate, the variations in the alveolar bone turnover rate and the variations in the clinical effectiveness of a functional appliance.

References