Nasal Growth and Maturation Age in Adolescents

A Systematic Review

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Objective: To define the end of the nasofacial growth spurt in order to schedule rhinoseptoplasty in patients with cleft without disturbing nasofacial growth.

Data Sources: We searched the PubMed and Cochrane bibliographic databases from inception through December 31, 2007, using the primary indexing term facial growth with the confining search terms growth AND (face OR nose) AND (cephalometry OR anthropometry). The reference lists of the retrieved articles were searched for missed relevant studies. Articles written in English, German, or Dutch were included in the review.

Study Selection: Studies of white adolescents without genetic disorders or malformations whose growth patterns had been followed up from at least 12 years of age until 18 years of age, with intervals between relevant measurements not longer than 2 years, were selected for this review.

Data Extraction: A reviewer performed data extraction by obtaining raw study data from the selected studies or by requesting them from the authors.

Data Synthesis: Growth velocity curves were fit to different relevant measures for nasofacial growth. The end of the nasofacial growth spurt was defined as the age at which these growth velocity curves have their steepest descending slope. This definition yielded an average age of 13.1 years for adolescent girls and 14.7 years for adolescent boys. Because no information could be found for the spread in age of nasal growth spurt of individuals, 2 SDs of the age distribution for body height growth velocity were added. This resulted in 98% of white adolescent girls being nasally mature at the age of 15.8 years and 98% of white adolescent boys being nasally mature at the age of 16.9 years.

Conclusion: Rhinoseptoplasty can safely be performed after the age of 16 years in girls and 17 years in boys.

them, improved appearance is even more important than better nasal function.17 However, if surgeons intend to fulfill this desire, they must take care not to disturb growth by respecting the limitations of rhinoseptoplasty. To that end, surgeons should be aware of the nasofacial growth pattern. Several authors18-22 suggest that the end of the nasofacial growth spurt takes place earlier than 18 years of age, but no conclusive research concerning children with or without cleft has been performed.

In our opinion, based on clinical experience at our otorhinolaryngology clinic, 5 measures are relevant in observing nasal growth (Figure 1): (1) nasal bridge length from nasion to pronasal; (2) nasal protrusion from subnasal to pronasal; (3) nasal height from nasion to subnasal; (4) palatal length from anterior nasal spine (ANS) to posterior nasal spine (PNS); and (5) midfacial protrusion from sella to ANS.

The aim of this study is to describe the nasofacial growth pattern of the normal child and adolescent to promote the identification of an adolescent growth spurt and the subsequent slowing of growth. From this, a definition of maturation is derived.

**METHODS**

**MATERIALS AND METHODS**

This article is based on a PubMed and Cochrane search from database inception to December 31, 2007. The following inclusion criteria were used to identify studies for this article: (1) white adolescents without genetic disorders or malformations; (2) growth pattern must be observed between the ages of 12 and 18 years; (3) facial growth evaluated through direct and/or indirect measurements; (4) intervals between measurement ages are not longer than 2 years; (5) the article must provide at least 1 of the 5 relevant measures; and (6) the article must be written in English, German, or Dutch.

Both libraries were searched on the keyword *facial growth*. Because of the large number of search results obtained from PubMed, we adjusted the relative search terms using *growth AND (face OR nose) AND (cephalometry OR anthropometry)*. The full text was obtained for articles considered relevant based on the title or the abstract. The reference lists of the retrieved articles were searched for relevant studies that could have been missed by the computer search.

The search yielded 25 articles and 1 book describing several nasofacial growth items.18-43 In 4 studies, the population was not white, in 10 studies* the measurements were not taken from 12- to 18-year-olds or followed up less than every 2 years, and in 8 studies22,25,30,33,37,39,40,43 elaborated or raw data could not be retrieved. The authors of these studies were requested by e-mail to clarify their data. This request yielded no additional information.

**STUDY SELECTION**

Farkas20 published extensive facial measurements in a reference book. Among many other measurements, results were found for nasal height, nasal protrusion, and nasal bridge length. In total, data were obtained transversally (50 persons per age) for 2326 white adolescents from Calgary, Alberta, Toronto, Ontario, Montreal, and Quebec, Canada, from birth to 25 years of age at intervals of 1 year.

*References 19, 21, 26, 28, 29, 31, 34, 38, 41, 42.

**STATISTICAL ANALYSIS**

The data included were plotted as a function of age. At approximately the age of maximum growth velocity, data were least squares fitted with an S-shaped curve with the following formula:

\[ y = a_1 \{ 1 - \exp[-a_2(x-x_1)] \} / \{ 1 + \exp[-a_3(x-x_2)] \} + a_4, \]

with \( y \) indicating length in millimeters and \( x \) indicating age in years; \( a_1, a_2, a_3, \) and \( x_1 \) are parameters to be fitted (Figure 2A).
Growth velocity as a function of age is obtained by differentiation of this formula (Figure 2B). The basis for the formulae used is the observation that growth proceeds at high velocity in early childhood and lower velocity in later childhood, with a growth spurt during adolescence that continues at a low steady pace until old age.20,27,28,38 The vertical scale in Figure 3 and Figure 4 is not expressed as growth velocity in millimeters per year; for a better comparison between the different measures, it is expressed as the percentage of the length at the age of 18 years per year. For example, if length at the age of 18 years is 50 mm, a velocity of 1 mm/y is thus 2% per year of the length at the age of 18 years.

The criterion chosen for maturity is the age at which the velocity curve descends most steeply. At this age, the second derivative of the formula is 0. From that age on, the growth velocity gradually decreases to almost 0.

RESULTS

Curves were fitted to 8 growth measures in female patients and to 6 measures in male patients (Figure 2A). The parameters that provided the best fits are given in Table 1 and Table 2. All measures for male and female patients show a period of growth acceleration. In girls (Figure 3), maximum growth velocity ranges from before the age of 8 years until the age of 12 years.32,36 In boys (Figure 4), all growth velocity curves (except 1) have their maximum at approximately the age of 13 years. Table 3 and Table 4 give the ages for maximum growth deceleration for girls and boys.

COMMENT

Palatal length lacks a growth spurt in adolescence in girls and boys and has a deviating growth pattern compared with the other nasal measures in boys and girls. This can
be explained by the fact that the PNS and ANS grow from
the sella. Although we did not select a study in which this is measured, it might be concluded that the PNS sella dis-
tance has an adolescent growth spurt parallel to the
ANS sella distance. Because of the lack of a growth spurt in adolescence, we consider palatal length not to be rep-
resentative of nasal maturation and have therefore not taken it into account.

The age of maturation can be defined in different ways. An obvious definition is the age at which the growth curve flattens to horizontal after the growth spurt during ado-
lescence. This, however, does not occur. Ferrario et al.,28
Farkas20,27 Lang et al.,29 West and McNamara,43 and particularly Zankl
et al27 have shown that the nose continues growing un-
til old age.

Farkas20 defined the age of maturation of the nose sta-
tistically by comparing distance measures at a certain age with the corresponding measure at 18 years of age, tak-
ing standard errors of the mean of the measurements into account. Personal correspondence by e-mail did not re-
veal the underlying rationale for this definition.

We have defined the age of maturity for a certain na-
sal measure as the age at which the growth velocity curve for this measure has its steepest descending slope. Ma-
turity ages for the representative measures are given in
Tables 3 and 4. The ANS-PNS values shown in Tables 3

<table>
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<tr>
<th>Source</th>
<th>Measure</th>
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<td>3.3197</td>
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**Table 3. Age of Maximum Growth Deceleration (the Age At Which the Second Derivative of the Velocity Curve Is Zero) in Adolescent Girls**

Abbreviations: ANS, anterior nasal spine; PNS, posterior nasal spine.

At approximately the age of maximum growth velocity, data were least squares fitted with an S-shaped curve with the following formula:

$$y = a_1 \left( \frac{1}{1 + e^{-a_2(x - x_1)}} \right) + a_0$$

where $y$ indicates length in millimeters and $x$ indicates age in years; $a_1$, $a_2$, $a_0$, and $x_1$ are parameters to be fitted.

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**Table 4. Age of Maximum Growth Deceleration (the Age At Which the Second Derivative of the Velocity Curve Is Zero) in Adolescent Boys**

Abbreviations: ANS, anterior nasal spine; PNS, posterior nasal spine.

These numbers are not taken into account (see the “Comment” section).
and 4 for girls and boys\textsuperscript{36} and \textsuperscript{32} deviate largely from the other values. This finding is unremarkable because palatal length lacks a growth spurt during adolescence. It has a growth pattern that deviates from that of other nasal measures because PNS and ANS grow from the sella\textsuperscript{46}, considered to be a stable point of the skull base during growth.\textsuperscript{47}

If palatal length is not taken into account, the average age of maturity is 13.4 years for girls and 14.7 years for boys. These numbers are in agreement with results from cephalometric studies of facial growth (Burke and Hughes-Lawson\textsuperscript{10}, el-Batouti et al\textsuperscript{41}, Thilander et al\textsuperscript{42} and Bergersen\textsuperscript{43}). The larger spread in the position of the maxima of the growth velocity curves for girls (Figure 3) compared with boys (Figure 4) is remarkable.

If the average age of maturity in a large group of girls or boys follows a symmetric distribution, this age will be higher than the given values for half of the group. Unfortunately, no information could be found for the spread in individual nasal growth as a function of age. However, if we assume that this spread does not differ much from the spread in body height velocity, useful information can be derived from the results of the study by Berkey et al.\textsuperscript{48} These authors provide longitudinal height velocity standards for US adolescents. The data points in Figure 5 were derived from their Figure 1. An almost perfect fit to these points could be made with a gaussian curve. The maximum of the curve is at the age of 11.5 years for girls and 13.5 years for boys. The SD (derived from the fit parameters) is 1.2 years for girls and 1.1 years for boys.

Nasal growth velocity is maximal at the mean (SD) age of 11.0 (0.9) years for girls and 12.6 (0.3) years for boys. Therefore, it may be concluded that no substantial difference exists between the age of maximal body height velocity and the age of maximal nasal growth velocity. If (to be on the safe side) 2 SDs for the height velocity distributions are added to the average age of maturity for the nose (as defined in this article), an age of 15.8 years is obtained for girls and 16.9 years for boys.

In a systematic review, Flores-Mir et al\textsuperscript{49} found that skeletal maturity, determined by hand-wrist radiographic analysis, was well related to overall facial growth velocity. This finding supports the assumption that nasal growth velocity is related to body height velocity. Furthermore, it provides the possibility of determining the stage of individual growth.

In conclusion, in 98% of adolescent girls the nose is mature at the age of 15.8 years. For 98% of adolescent boys, this age is 16.9 years. Because the results of nasal interventions performed after maturation age are not likely to be disturbed by nasal growth, rhinoseptoplasty can be performed safely, in most cases, in adolescent girls after the age of 16 years and in adolescent boys after the age of 17 years.

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\textbf{Author Contributions:} All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

\textbf{Study concept and design:} van der Heijden, Korsten-Meijer, and Wit.

\textbf{Acquisition of data:} van der Heijden.

\textbf{Analysis and interpretation of data:} van der Heijden, Korsten-Meijer, van der Laan, Wit, and Goorhuis-Brouwer.

\textbf{Drafting of the manuscript:} van der Heijden, Korsten-Meijer, and Wit.

\textbf{Critical revision of the manuscript for important intellectual content:} van der Heijden, Korsten-Meijer, van der Laan, and Wit.

\textbf{Statistical analysis:} Wit.

\textbf{Obtained funding:} van der Heijden.

\textbf{Administrative, technical, and material support:} van der Heijden, van der Laan, and Wit.

\textbf{Study supervision:} Korsten-Meijer, van der Laan, Wit, and Goorhuis-Brouwer.

\textbf{Financial Disclosure:} None reported.

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