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Effects of extraction treatment on maxillary and mandibular sagittal development in growing patients

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SUMMARY This retrospective investigation was designed to assess the effects of extraction treatment on the sagittal dimensions of the maxillary and mandibular skeletal structures of growing patients.

The records of 40 patients (17 girls, 23 boys; median age 10 years 11 months) whose orthodontic treatment involved extraction of four premolars were evaluated and compared with a control group of 100 patients (54 girls, 46 boys; median age 10 years 7 months) treated non-extraction. Two lateral cephalograms were obtained of each patient, the first before the extractions, T1, and the second at a later point, T2 (mean difference 59 months). Linear parameters, including S–N, the maxillary/mandibular alveolar process, and maxillary/mandibular base, were measured. The same parameters were determined in the control group at corresponding time points (mean difference 63 months). For analysis, the sagittal dimensions of the alveolar processes and jaw bases were compared with each other. The relationships were also established to a reference line known to be unaffected by extraction treatment (S-N). This procedure was performed for the whole sample and for three subgroups formed according to the Wits appraisal. Statistical analysis was carried out using a Student's *t*-test.

Comparisons of the total sample showed differences between the groups, which were statistically significant for the maxillary alveolar process, the mandibular alveolar process, and the mandibular base. They varied however in the different subgroups.

Whenever extraction treatment is considered, it should be borne in mind that the effects on the sagittal dimension of different bony structures may vary.

Introduction

A large number of studies have investigated the effects of extraction treatment on facial profiles and soft tissue structures in children and adolescents (Dobrocky and Smith, 1989; Paquette *et al.*, 1992; Staggers, 1994; Bishara *et al.*, 1997; Boley *et al.*, 1998; Zierhut *et al.*, 2000). Although this issue has produced controversial debate, precise relevant data are readily available. Whether extraction treatment might also affect the underlying bony structures is less well documented. No detailed information is available concerning osseous alterations, although numerous authors have identified degenerative or atrophic alterations following tooth loss, periodontal health problems, or tooth agenesis (Andreasen *et al.*, 1994; Jacobson and Modéer, 1994; Stöckli, 1994; Kahl-Nieke, 1995; Tiefengraber *et al.*, 2002). Most studies, however, evaluated skeletal development and growth in the vertical and transverse dimensions. Janson *et al.* (2003) reported that larger distances between the alveolar process and the cementoenamel junction exist in teeth located adjacent to edentulous areas where extraction treatment had been performed than in subjects treated without extractions. Kennedy *et al.* (1983) reported comparable results based on a standard study design. Ostler and Kokich (1994) investigated how extraction of the second primary molars in children with agenesis of the mandibular second premolars affected the width of the alveolar process. They found that pronounced differences exist. In contrast to this considerable body of information, very little evidence is available to determine the effects on the sagittal dimension.

Thus, the aim of this study was to investigate the skeletal effects of extraction therapy, addressing the degree to which the removal of teeth will affect the sagittal dimensions of skeletal structures during ongoing growth. Particular emphasis was placed on potential differences between the maxilla and mandible.

Subjects and methods

Inclusion criteria

The patients enrolled in this study included young Caucasians without any abnormalities such as hypodontia, hyperdontia, syndromes, surgical history, or maxillofacial trauma. All had been treated with removable appliances in the upper and lower jaws and then with fixed appliances (multibracket appliances).

From a total of 42 patients in the extraction group and 105 in the control group, two patients in the extraction group and five in the non-extraction group were excluded from the sample because the difference of the angular parameter SN–MeGo was greater than 1 degree. Analysis was thus based on 40 patients (17 girls and 23 boys) in whom four premolars (one per quadrant) had been extracted for orthodontic reasons. They were compared with a control group of 100 patients (54 girls and 46 boys) who had been treated non-extraction.

To allow for comparability regarding the skeletal morphology of the patients, three different groups were formed according to the criteria given by the Wits appraisal (Jacobson, 1976). According to this description, a normal occlusion would be 0 in females and −1 in males. This was defined as 'Wits Class I'. Smaller values were defined as 'Wits Class III' and larger values as 'Wits Class II'. Thus, 21 patients in the control group and 4 in the extraction group were classified as Wits Class I, 37 patients in the control group and 18 in the extraction group as Wits Class II, and 42 patients in the control and 18 in the extraction group as Wits Class III.

Two lateral cephalograms of each patient were analyzed. Chronological age averaged 131 months in the extraction group and 127 months in the control group at the first examination (T1). In the extraction group, there was a time span of at least 2 years between T1 and T2. The mean interval between T1 and T2 was 59 months in the extraction group and 63 months in the control group.

All radiographs were obtained using the same cephalostat with a magnification of 9 per cent at the Faculty of Dentistry, University of Tübingen. The distance of the patient to tube was 4 m. Positioning was done by adjusting the Frankfort plane of the patient parallel to the floor.

Cephalometric analysis

For cephalometric analysis, 15 reference points were defined, including a number of linear parameters and one angular parameter (Figure 1). Relevant distances were defined and measured on transparent acetate film in accordance with the principles reported in the literature (Riolo *et al.*, 1974; Rakosi, 1979). More recently, Kajii *et al.* (2004) described a similar approach. Figure 1 illustrates the distances measured and the auxiliary lines and reference points that were needed to construct these distances.

Statistical analysis

Two different aspects were considered in analyzing the generated data.

Direct comparison of parameters. The arithmetic means obtained for the four parameters (maxillary/mandibular alveolar process and maxillary/mandibular base) based on the lateral cephalograms at T1 and T2 were compared separately for the extraction and control group.

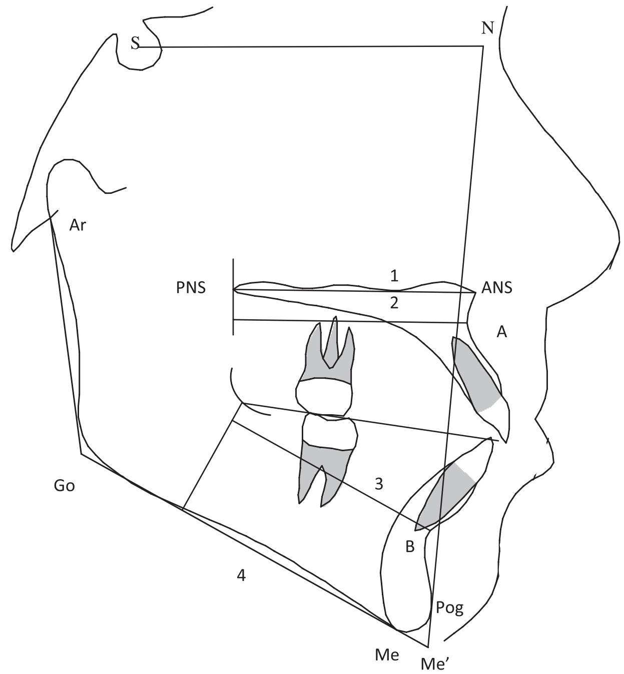

Figure 1 The measured linear and angular parameters and their definitions. Linear parameters—sella (S)–nasion (N); nasion (N)–pogonion (Pog) and menton (Me)–gonion (Go): the intersection of both lines defines Menton' (Me'); occlusal plane: distance between the bisector of the overjet and the most posterior contact point of the first permanent molar; Wits appraisal: distance between the points of perpendiculars from points A and B onto the occlusal plane (Jacobson, 1976); maxillary base: ANS–PNS (marked by '1'); maxillary alveolar process: point A and intersection of a line perpendicular to the maxillary base through posterior nasal spine. This parameter forms a line parallel to the maxillary base (marked by '2'); mandibular alveolar process: point B and intersection of a line perpendicular to the mandibular base where the occlusal plane intersects with the ascending ramus of the mandible. This parameter forms a line parallel to the mandibular base (marked by '3'); and mandibular base: gonion–menton' (Me', marked by '4'). Angular parameter—SN–MeGo: this angle was measured on both lateral cephalograms to avoid distortion of the measurement results of the mandibular base as a function of different growth patterns. Any differences greater than 1 degree were not considered acceptable. Patients with growth patterns showing larger differences were excluded from the study.

By comparing the mean values for each parameter at T1 and T2, it was possible to determine whether the extractions created a difference in the sagittal dimension compared with the control group. A Student's *t*-test was used to identify any significant intergroup differences. These differences allowed for comparison of mean quantitative changes observed for each parameter in both groups.

Comparison of parameters after adjustment by S–N. For a more objective appraisal of the degree of change specific bony structures with extraction treatment, each of the linear parameters measured was additionally related to a linear parameter known to be unaffected by extraction treatment. S–N was considered an appropriate reference distance (Rakosi, 1979).

Adjustment for S–N was accomplished by converting the mean absolute values obtained for each parameter based on the lateral cephalograms at T1 and T2 to the percentage values in relation to S–N. The differences between these percentage values indicated the growth increase for each parameter as it related to S-N.

By comparing parameter-specific differences between the extraction and control group, information was obtained about the relative effects of extraction treatment on growth development specific to each parameter.

Data were analyzed with version 5.1 of JMP-IN statistical software (SAS Institute Inc., Cary, North Carolina, USA).

Systematic error

All radiographs were analyzed by a single investigator (MK). Thirty randomly selected lateral cephalograms were re-examined after a 2-month interval in order to test intraexaminer reliability. All parameters were analyzed for their systematic error using the formula of Dahlberg (1940): $ME = \sqrt{\sum d^2 / 2n}$, where d is the difference between two measurements of the same parameters, while n is the number of measurements performed in duplicate. The systematic error ranged between 0.3 and 0.6 mm for linear measurements and was 0.5 degrees for the angular measurement, thus confirming reliability.

Results

Direct comparison of parameters

Overall results. At T1, the differences between the mean values in the extraction and control groups were very small for the maxillary alveolar process and maxillary base. For the corresponding mandibular parameters, the mean values were almost identical in both groups.

At T2, the intergroup differences were markedly greater for each parameter measured. A statistically significant difference (P = 0.0222) was noted between the values for the maxillary alveolar process. Differences were even more pronounced in the mandible and highly significant for the mandibular alveolar process (P = 0.0001) and the mandibular base (P = 0.0006; Table 1).

Wits Class I. The mean values for all four parameters were very similar or identical at T1 and T2. Table 2 gives an overview of the mean values and standard deviations (SDs)

Table 1 Mean lengths in millimeters of the four linear parameters measured for all subjects in both groups at two different time points (T1 first examination, T2 follow-up).

	Control group (n = 100)						Extraction group (n = 40)							
	T1		T2		Difference		T1		T2		Difference			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P	Significance
Maxillary alveolar process	47.6	2.7	50.1	3.2	2.5	2.2	46.9	3.2	48.4	3.3	1.5	2.8	0.0222	*
Maxillary base	53.2	3.2	56.5	3.9	3.3	2.7	52.8	3.7	55.7	4.0	2.9	3.4	0.4197	NS
Mandibular alveolar process	45.6	2.9	50.5	2.7	4.9	2.5	45.5	3.2	47.7	3.1	2.2	2.5	0.0001	***
Mandibular base	74.8	4.2	82.4	5.0	7.6	4.4	74.6	6.4	79.3	6.0	4.7	4.8	0.0006	***

The P values show statistically significant intergroup differences between the intragroup-specific differences for each parameter. NS, not significant; *P < 0.05; ***P < 0.001.

Table 2 Mean lengths in millimeters of the four linear parameters measured in both groups for Wits Class I at two different time points (see Table 1). SD, standard deviation.

	Control group (n = 21)						Extraction group (n = 4)							
	T1		T2		Difference		T1		T2		Difference			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P	Significance
Maxillary alveolar process	47.1	2.3	50.6	3.2	3.5	2.0	47.3	6.0	49.3	3.9	2.0	5.2	0.6036	NS
Maxillary base	52.7	3.1	57.2	4.2	4.5	2.8	52.8	7.0	55.8	5.3	3.0	4.5	0.5695	NS
Mandibular alveolar process	45.0	2.9	50.6	3.4	5.6	1.8	45.0	2.7	49.5	1.0	4.5	2.6	0.4686	NS
Mandibular base	73.5	4.5	83.2	6.4	9.7	4.2	74.3	3.6	82.0	5.0	7.7	3.8	0.3858	NS

The P values show statistically significant intergroup differences between the intragroup-specific differences for each parameter. NS, not significant.

obtained for each parameter based on the lateral cephalograms at T1 and T2 for the Wits Class I group.

Wits Class II. The differences between the intragroup differences of the mean values at T1 and T2 were small and not significant for the maxillary alveolar process or for the maxillary base.

They were, however, significant for the mandibular alveolar process and the mandibular base, showing that growth of these two anatomical structures was greatly reduced in the extraction group ($P = 0.0001$ and $P = 0.0037$, respectively). The mean values and SDs obtained for each parameter based on the lateral cephalograms at T1 and T2 for the Wits Class II group are shown in Table 3.

Wits Class III. The differences between the intragroup differences of the mean values at T1 and at T2 were small and not significant for measurements of the maxilla and mandibular base.

A significant difference was found for the mandibular alveolar process revealing a lack of growth in the extraction group ($P = 0.0029$).

An overview of the mean values and SDs obtained for each parameter based on lateral cephalograms at T1 and T2 for the Wits Class III group are shown in Table 4.

Comparison of parameters after adjustment by S–N

Overall results. Once the absolute values for all measured parameters were converted to percentage values in relation to S–N, similar intergroup differences were observed that corresponded to the differences in the absolute values. At T1, the adjusted values were largely similar in both groups, but larger differences in three of the four parameters were noted when comparisons were based on images at T2 (Table 5).

These relative values confirmed the results obtained in absolute terms. Again, the maxillary base did not demonstrate a noteworthy effect. A small effect was apparent for the maxillary alveolar process, while the intergroup differences for both the mandibular alveolar process and mandibular base were pronounced.

Wits Class I. The adjusted mean values for all four parameters were very similar at T1 and T2. Consequently, there were only small intergroup differences. However, all of these differences showed a reduction of growth in the extraction group (Table 6).

Wits Class II. There was no intergroup difference of the adjusted mean values at T1 and at T2 for the maxillary

Table 3 Mean lengths in millimeters of the four linear parameters measured in both groups for Wits Class II at two different time points (see Table 1).

	Control group ($n = 37$)						Extraction group ($n = 18$)							
	T1		T2		Difference		T1		T2		Difference			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*	Significance
Maxillary alveolar process	48.7	2.7	51.1	2.9	2.4	2.2	47.5	3.0	49.1	2.5	1.6	2.4	0.2513	NS
Maxillary base	54.4	3.2	57.8	3.6	3.4	2.8	53.4	3.1	56.4	3.4	3	3.5	0.6547	NS
Mandibular alveolar process	44.8	2.6	50.2	2.3	5.4	2.7	45.1	3.6	47.2	2.9	2.1	2.2	0.0001	***
Mandibular base	74.7	3.9	82.8	3.9	8.1	4.0	75.7	7.9	78.9	5.8	3.2	5.8	0.0037	*

The *P* values show statistically significant intergroup differences between the intragroup-specific differences for each parameter. NS, not significant; $*P < 0.05$; $***P < 0.001$.

Table 4 Mean lengths in millimeters of the four linear parameters measured in both groups for Wits Class III at two different time points (see Table 1).

	Control group ($n = 42$)						Extraction group ($n = 18$)							
	T1		T2		Difference		T1		T2		Difference			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*	Significance
Maxillary alveolar process	46.8	2.6	48.9	3.0	2.1	2.2	46.3	2.6	47.4	3.8	1.1	2.7	0.2346	NS
Maxillary base	52.3	3.1	54.9	3.5	2.6	2.5	52.2	3.5	54.9	4.4	2.7	3.2	0.9262	NS
Mandibular alveolar process	46.6	2.9	50.6	2.7	4.0	2.5	46.0	2.9	47.7	3.4	1.7	2.6	0.0029	*
Mandibular base	75.5	4.2	81.7	5.0	6.2	4.4	73.7	5.1	79.1	6.5	5.4	3.4	0.4820	NS

The *P* values show statistically significant intergroup differences between the intragroup-specific differences for each parameter. NS, not significant; $*P < 0.05$.

Table 5 Percentage values for all four parameters measured for all subjects in both groups relative to the reference distance S–N at two different time points (see Table 1).

	Control group (n = 100)			Extraction group (n = 40)		
	T1, %	T2, %	Δ(T2 − T1), %	T1, %	T2, %	Δ(T2 − T1), %
S–N/maxillary alveolar process	68.2	68.7	+ 0.5	67.4	66.9	−0.5
S–N/maxillary base	76.3	77.5	+1.2	75.9	77.1	+1.2
S–N/mandibular alveolar process	65.4	69.3	+3.9	65.3	65.9	+ 0.6
S–N/mandibular base	107.2	113.2	+6.0	107.2	109.7	+2.5

Comparison of increases in growth of each parameter measured shows differences between the extraction and the control group.

Table 6 Percentage values for all four parameters measured relative to the reference distance S–N in both groups for Wits Class I at two different time points (see Table 1).

	Control group (n = 21)			Extraction group (n = 4)		
	T1, %	T2, %	Δ(T2 − T1), %	T1, %	T2, %	Δ(T2 − T1), %
S–N/maxillary alveolar process	67.9	69.1	+1.2	68.7	68.6	−0.1
S–N/maxillary base	76.0	78.1	+2.2	76.7	77.7	+1.0
S–N/mandibular alveolar process	64.9	69.1	+4.2	65.4	69.3	+3.9
S–N/mandibular base	105.8	113.5	+7.7	108.0	114.5	+6.5

Comparison of increases in growth of each parameter measured shows differences between the extraction and the control group.

alveolar process. There was a minimal difference for the maxillary base, demonstrating slightly more growth in the extraction group.

There were however considerable differences in the mandible showing that growth of these two anatomical structures was reduced in the extraction group in the mandibular alveolar process and in the mandibular base.

Table 7 gives an overview of the adjusted mean values and differences for the Wits Class II group.

Wits Class III. The intergroup differences between the mean values at T1 and T2 were very small for both measurements in the maxilla and for the mandibular base, revealing less growth in the extraction group.

A considerable difference was found for the mandibular alveolar process revealing a lack of growth in the extraction group compared with the control group (Table 8).

Discussion

The presence of teeth and periodontal structures is related to growth and, hence, to the development of skeletal structures. The existence of such a relationship seems to be generally accepted, as numerous authors have come to the same conclusion from a variety of perspectives. Although the literature concerning changes in the vertical and transverse dimensions is replete, only a few authors have reported on the sagittal effects. Stellzig *et al.* (1996) found that maxillary growth was inhibited after second molar extractions when treating Class II malocclusions. They did not, however, compare these findings to patients treated by other means. Bishara (1998) studied a group of patients whose first premolars had been extracted, reporting that more pronounced alterations were observable regarding the relationship between the mandible and maxilla than in a group of patients who had undergone non-extraction treatment. The present study confirmed these findings of skeletal alterations with extraction treatment. The findings also provide information about the extent of these changes in the sagittal dimension following premolar extractions, which is a relatively common therapy.

Stöckli (1994) suggested that extractions can have different effects depending on whether they are performed in the maxilla or mandible. He pointed out that extraction of four premolars carries a risk of 'intermaxillary discoordination with dissatisfying outcomes'. This view is consistent with the current results to the extent that the patient sample showed different effects with maxillary and mandibular extractions. The finding that the mandible is particularly affected by reduced sagittal growth might well account for the 'intermaxillary discoordination' proposed by Stöckli (1994).

Although the reduction of growth of the alveolar processes could be explained through the effects of extraction treatment, the question still remains as to why the effect on point A is less than on point B. One explanation might be that the mandible will frequently continue to grow even after maxillary growth has been completed (Battagel and Orton, 1993; Kreiborg *et al.*, 1994; Stöckli, 1994;

Table 7 Percentage values for all four parameters measured relative to the reference distance S–N in both groups for Wits Class II at two different time points (see Table 1).

	Control group (n = 37)			Extraction group (n = 18)		
	T1, %	T2, %	Δ(T2 − T1), %	T1, %	T2, %	Δ(T2 − T1), %
S–N/maxillary alveolar process	68.9	68.9	0	67.3	67.3	0
S–N/maxillary base	77.1	78.1	+1.0	75.7	77.4	+1.7
S–N/mandibular alveolar process	63.4	67.7	+4.3	63.8	64.7	+0.9
S–N/mandibular base	105.8	111.9	+6.1	107.1	108.2	+1.1

Comparison of increases in growth of each parameter measured shows differences between the extraction and the control group.

Table 8 Percentage values for all four parameters measured relative to the reference distance S–N in both groups for Wits Class III at two different time points (see Table 1).

	Control group (n = 42)			Extraction group (n = 18)		
	T1, %	T2, %	Δ(T2 − T1), %	T1, %	T2, %	Δ(T2 − T1), %
S–N/maxillary alveolar process	67.8	68.4	+0.6	67.3	66.3	−1.0
S–N/maxillary base	75.7	76.9	+1.2	75.9	76.7	+0.8
S–N/mandibular alveolar process	67.5	70.8	+3.3	66.9	66.6	−0.3
S–N/mandibular base	109.4	114.3	+4.9	107.2	110.5	+3.3

Comparison of increases in growth of each parameter measured shows differences between the extraction and the control group.

Zierhut *et al.*, 2000). Thus, it appears plausible that the effects of extraction treatment on growth and development would be more pronounced in the mandible.

In addition, mandibular growth is subject to individual differences. Petrovic *et al.* (1986) provided a classification ranging from category 1 (least pronounced mandibular growth) to category 5 (most pronounced mandibular growth). Moro *et al.* (2000) performed a comparative study of Class II patients who had undergone extraction treatment. They concluded that such treatment is more likely to be indicated in patients falling into category 3 according to Petrovic *et al.* (1986) than those falling into category 5. In other words, extraction treatment is increasingly discouraged in patients with strong mandibular growth. The present findings are consistent with this recommendation, to the extent that greater effects of extraction treatment in the presence of stronger growth were observed.

Concerning the different subgroups, it is difficult to compare the results with other studies since most used Angle's classification for categorization which is based on dental parameters that do not necessarily correspond to the given skeletal patterns.

Concerning the Wits Class II and III, more pronounced effects were found in the mandible. In a group of Class II patients, Bishara (1998) described a 'normalization of the skeletal relationships' for both extraction and non-extraction groups compared with normal subjects with pronounced effects in the extraction group. However, that author did not provide exact measurements of the skeletal structures. Paquette *et al.* (1992) found skeletal effects in the mandible using discriminant analysis that principally correspond to the present results; different measurement points may explain differences regarding the actual amount. This also applies to the work of Luppanapornlarp and Johnston (1993) who described a 'significantly greater reduction in hard and soft tissue protrusion' after premolar extraction but failed to find significant differences in the mandible between either group.

Battagel and Orton (1991) investigated Class III patients and found more pronounced mandibular skeletal effects in a non-extraction group than in an extraction group. However, treatment time in the extraction group was longer than in the non-extraction group, the period investigated was shorter than in the current study, the patients in the extraction group were of an older age than those in the present research, and headgear was used to an intact mandibular dentition. Each of these points could explain the difference in the results.

An issue frequently raised in connection with orthodontic extraction treatment concerns its potential effects on the facial profile. A number of reports have been published on this topic. Most observations do not support the idea that extraction of teeth significantly affects facial profiles (Dobrocky and Smith, 1989; Staggers, 1994; Bishara *et al.*, 1997; Jäger *et al.*, 1997; Boley *et al.*, 1998; McLaughlin and Bennett, 1998). A minority of authors have reported profile flattening leading to a more concave shape (Paquette *et al.*, 1992; Zierhut *et al.*, 2000). With regard to the maxilla, the results support the former view. Any skeletal effects observed in the maxilla were small. Hence, it would appear plausible that extraction treatment is not capable of inducing changes in this part of the human face.

In the mandible, the results would theoretically support an effect of extractions on facial profiles. Nevertheless, it should be borne in mind that the reaction of soft tissue structures to any skeletal change cannot reliably be predicted or determined. Katsaros *et al.* (1996) reported that soft tissue alterations following extraction treatment vary considerably from patient to patient, and Singh (1990) failed to establish a correlation between soft tissue architecture of the chin and previous premolar extractions.

Conclusions

Based on the results of this study, it appears justified to draw the following conclusions:

1. Extraction treatment during growth will affect growth of the skeletal structures within the maxillofacial area.
2. In Wits Class II and III patients, more pronounced effects should be expected in the mandible than in the maxilla. Particularly affected are the mandibular alveolar processes in Wits Class II and III patients and the mandibular base in Wits Class II patients.
3. The observation of different effects in the maxilla or mandible in certain skeletal Classes should be borne in mind whenever extraction treatment is considered in patients who have not completed growth.

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