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The influence of cephalometrics on orthodontic treatment planning

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SUMMARY Since its introduction, cephalometrics, i.e. cephalometric radiography and analysis, has been used for orthodontic treatment planning. However, the effectiveness of this diagnostic method remains questionable. A randomized crossover study was designed to assess the influence of cephalometrics in orthodontic treatment planning of individual patients. Diagnostic records of 48 subjects (24 males and 24 females aged 11–14 years) were divided in two stratified groups and assigned to one of two combinations: A, dental casts only, and B, dental casts, cephalometric radiographs, and analysis. The records were presented to 10 orthodontic postgraduates and four orthodontists for formulation of orthodontic treatment plans containing a dichotomous decision regarding the use of a functional appliance (FUNC), rapid maxillary expansion (RME), and extraction (EXTR). The combination of FUNC + RME + EXTR was used as the basis of the outcome measure. Agreement on orthodontic treatment planning using all possible comparisons of diagnostic records of individual patients (AB, AA, and BB) was assessed and overall proportions of agreement (OPA) were calculated for orthodontic postgraduates and orthodontists separately.

Median OPA were 0.60 (AB), 0.65 (AA), and 0.60 (BB) for orthodontic postgraduates and 0.50 (AB), 0.75 (AA), and 0.50 (BB) for orthodontists. Irrespective of the level of experience, neither consistency of orthodontic treatment planning between both combinations of diagnostic records showed a statistically significant difference ($P > 0.05$) using Wilcoxon signed rank test nor did consistencies and agreement of orthodontic treatment planning after the addition of cephalometrics. It appears that cephalometrics are not required for orthodontic treatment planning, as they did not influence treatment decisions.

Introduction

Cephalometrics, that is cephalometric radiography and analysis, is considered to be part of the 'gold' standard for diagnosis at the start of orthodontic treatment. Dental casts, intra- and extra-oral photographs, and panoramic and cephalometric radiographs are advised to be used routinely for orthodontic treatment planning (Graber and Vanarsdall, 2000; Proffit and Fields, 2000). Most clinicians indeed use cephalometrics for orthodontic treatment planning. For instance, in 2002, 90 per cent of orthodontists in the United States routinely obtained cephalograms (Keim *et al.*, 2002). The prevalence of the routine use of cephalometrics among European orthodontists is unknown, but the latest published guidelines for the use of radiographs by European orthodontic societies indicate the 'indispensability of a lateral skull radiograph in patients with skeletal discrepancy when functional appliances and/or two arch fixed appliances are to be used for appreciable apical movement of incisors' (Deutsche Geschellschaft für Kieferorthopädie, 1997; Isaacson and Thom, 2001). The European Union endorses these guidelines with respect to the indication for taking radiographs at the start of orthodontic treatment (European Commission, 2004).

However, the actual contribution of cephalometric radiography to orthodontic treatment planning remains questionable. The literature provides neither cost–benefit analysis nor sufficient evidence with regard to cephalometric radiography in orthodontic treatment planning in terms of treatment time reduction, quality performance, or prediction of results. It has been suggested that dental casts and initial clinical examination alone provide adequate information for orthodontic treatment planning (Han *et al.*, 1991; Bruks *et al.*, 1999). Additional radiographs might provide more information about the severity of the malocclusion, but has minimal influence on the level of certainty regarding orthodontic treatment planning (Atchison *et al.*, 1991; Pae *et al.*, 2001).

In accordance with the Directive 97/43/EURATOM, radiographic exposure is justified only when the management of the patient depends on the information obtained from the radiograph. Furthermore, exposure should be as low as reasonably achievable (European Commission, 1997). Radiographic exposure should counterbalance no radiographic exposure in terms of utilization and effectiveness of diagnostic information.

Therefore, the aim of this study was to assess whether cephalometrics, as a diagnostic record, is of influence on orthodontic treatment planning of individual patients. The null hypothesis to be tested is that agreement in decisions with and without cephalometric information is equal to the consistency of the decisions within one condition.

Materials and methods

Subjects

Pre-treatment diagnostic records, including dental casts and cephalometric and panoramic radiographs, of subjects treated between October 1994 and March 2003 at the Department of Orthodontics, Academic Centre for Dentistry Amsterdam, were selected. These subjects fulfilled the following requirements: (1) Caucasian males and females between 11 and 14 years of age, (2) bilateral Class II buccal segment relationship of more than one-half cusp width when the primary lower second molars were still present, (3) bilateral Class II buccal segment relationship of at least one-half cusp width when the permanent teeth in the lateral segments had erupted, (4) overjet of 6 mm or more, (5) absence of craniofacial or dental malformations, and (6) absence of tooth agenesis.

To assess the influence of cephalometrics on orthodontic treatment planning, not on the consistency of orthodontic treatment planning of clinicians, but as an additional diagnostic record which might give more information on dentofacial characteristics of individual patients, a power analysis was conducted to determine the number of patients necessary. The clinically relevant difference (d) in proportion agreement of orthodontic treatment planning after the addition of cephalometric radiography was selected as 0.25. This difference of 0.25 corresponds with a medium effect size. With an alpha level of 0.05 and a power of 80 per cent, a sample size of 48 patients, 24 males and 24 females, was needed (Cohen, 1988).

Design of the study

A randomized crossover design was used in which two conditions for the diagnostic records were created. The first contained only dental casts, while in the second cephalometric radiographs and cephalometric values were added to the dental casts. Using gender, age in years, overjet in millimetres, and molar relationship in cusp width as strata, the 48 patients were randomly allocated to either sequence I or sequence II, T1. At least 1 month later, the conditions were changed (T2).

To assess the consistency of orthodontic treatment planning of condition A and B, the randomized crossover procedure was repeated at least 1 (T3) and 2 (T4) months after T2. The design of the study is shown in Figure 1.

Procedure and materials

At T1, available records of each subject were presented in a random order. Personal identity of the pre-treatment

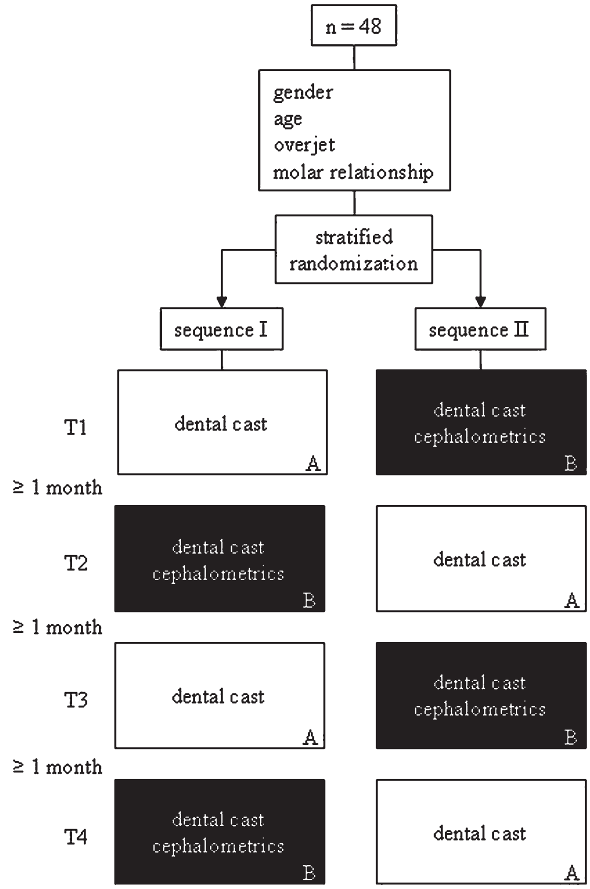

Figure 1 Design of the study. Based on gender, age, overjet, and molar relationship, 48 patients were randomly allocated to sequence I or II (T1). After 1 month, conditions A and B were changed (T2). The randomized crossover procedure was repeated at least 1 (T3) and 2 (T4) months after T2.

diagnostic records of the subjects was hidden. The records were numbered and only gender and age of the subject were displayed. Before T2, T3, and T4, the diagnostic records were randomly renumbered and reordered to avoid possible bias. At each time point, 10 orthodontic postgraduates and four orthodontists formulated orthodontic treatment plans using the available diagnostic records. There was a period of at least 1 month between each time point to exclude (memory) bias. The orthodontic treatment plan consisted of a dichotomous decision (yes/no) regarding the use of three orthodontic treatment modalities: functional appliance (FUNC), rapid maxillary expansion (RME), and extraction (EXTR). The combination of dichotomous decisions regarding these modalities (FUNC + RME + EXTR) was used as the basis of the outcome measure in this study.

Each clinician was given the following additional information before planning treatment:

1. The subject's main complaint is crowding, a large overjet or a combination.
2. Treatment outcome goals are well-aligned dental arches with a Class I canine relationship.

3. To realize these goals, each specific treatment modality (FUNC, RME, and EXTR) might be followed by full fixed appliances. Prior to or during full fixed appliance therapy, all possible alternatives to correct the Class II malocclusion were allowed.
4. A combination of the treatment modalities (FUNC, RME, or EXTR) was allowed to achieve treatment goals within one subject.
5. The subjects would demonstrate typical compliance.
6. Unlimited resources were available for treatment.
7. Absence of syndromes and dental developmental or craniofacial malformations.
8. No tooth agenesis was present.

Cephalometrics

All cephalometric radiographs were digitized by one investigator (PGN) using Viewbox©1.9 software (dHAL Kifissia, Greece). The analyses of Downs (1948, 1952) Steiner, (1953, 1959, 1960) and Tweed, (1954) and Wits appraisal (Jacobson, 1975) were used. All measurements were repeated to assess intra-examiner reliability within 2 weeks. The intraclass correlation coefficient was within acceptable limits (r = 0.93). In the second condition, cephalometric radiographs as well as the cephalometric values resulting from the above-mentioned procedure (mean of the two measurements) were determined.

Data analysis

The combination (FUNC + RME + EXTR) of dichotomous decisions was used as the basis of the outcome measure in this study. The threefold decision based on condition A and condition B at T1 and T2 was compared (AB and BA). Only if the decision for condition A and B was identical for all three modalities, agreement in orthodontic treatment planning was scored 1, whereas disagreement was scored 0; agreement was categorically assessed for each patient and for each clinician separately.

To quantify agreement on treatment planning (FUNC + RME + EXTR) for each individual orthodontic patient, an overall proportion of agreement (OPA) was calculated for the 10 orthodontic postgraduates and four orthodontists. For example, an OPA of 0.50 for orthodontic postgraduates meant that five of the 10 postgraduates did not change their subjective treatment plan after assessment of the alternative condition for that patient. OPA was used as the final, quantitative, outcome measure.

To test whether an order effect of the conditions (AB, BA) was present, a Mann–Whitney U-test was then conducted to determine whether there was a difference in OPA (T1–T2) between sequence I and sequence II. If no statistically significant difference was present, the order in which the conditions were presented did not bias the results, and the data for both sequences could be pooled.

In addition, consistency of orthodontic treatment planning was determined within the conditions (AA and BB) in the same way. An OPA was calculated per patient over the clinicians based on the comparison of condition A (AA) at two time points (T1–T3 and T2–T4) and of comparison of condition B (BB) at two time points (T1–T3 and T2–T4).

A Wilcoxon signed rank test was used to assess whether cephalometric information changed the orthodontic treatment planning decision. The OPA between condition A and B (AB) from T1 and T2 should be lower than the consistency proportion of the treatment decisions within the conditions (AA and BB) at different time points if cephalometric information is of influence on the treatment decision.

Furthermore, differences between consistency of treatment planning with and without cephalometrics (AA versus BB) were assessed using a Wilcoxon signed rank test.

Non-parametric Mann–Whitney U- and Wilcoxon signed rank tests were used since normal data distribution could not be assured. The Statistical Package for Social Sciences 14.0 for Windows (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The level of statistical significance for all tests was set at $\alpha = 0.05$.

Results

Mann–Whitney U-tests showed no condition-order effect for orthodontic postgraduates (P = 0.48) or orthodontists (P = 0.58). Therefore, OPA of orders AB and BA were pooled for each group of clinicians. Figure 2 and Table 1 depict descriptive statistics and box plots of the OPA for the orthodontic postgraduates and orthodontists.

The median OPA between condition A and B for the orthodontic postgraduates was 0.60 and ranged from 0.10 (minimum) to 1 (maximum). Using only dental casts, the postgraduates' median OPA was 0.65 (range 0.20–1), and using cephalometrics in addition to dental casts, the median OPA was 0.60 (range 0.10–1).

No statistically significant differences were present in OPA between condition A and B on the one hand and consistency of treatment planning using only dental casts (P = 0.20) or cephalometric information in addition to the dental casts (P = 0.28) on the other. Consistency of treatment planning did not differ significantly (P = 0.74) between the use of only dental casts or with additional cephalometric information.

For the orthodontists, the median OPA between condition A and B was 0.50 (range 0–1). Using only dental casts, the median OPA was 0.75 (range 0–1), and using cephalometrics in addition to dental casts, the median overall score was 0.50 (range 0–1). No statistically significant differences were present in OPA between condition A and B on the one hand and consistency of treatment planning using only

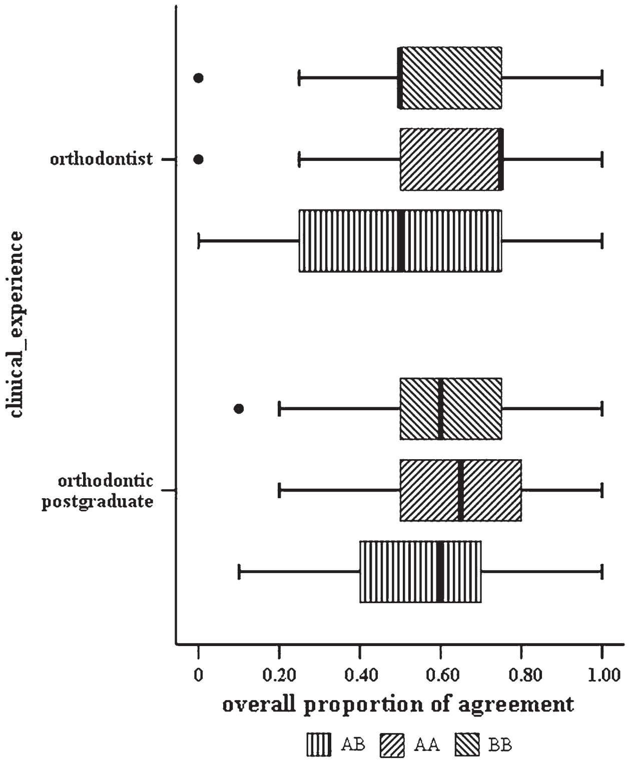

Figure 2 Box plots of overall proportions of agreement on orthodontic treatment planning using combinations of different and identical diagnostic records. Vertical black line in each box represents the median value. Box length is the interquartile range, between the 25th and 75th percentile. Vertical lines outside the box represent the minimum and maximum. Black dots represent outliers, cases with values between 1.5 and 3 box lengths from the left or right edge of the box.

Table 1 Descriptive statistics of overall proportions of agreement of orthodontic residents and orthodontists on orthodontic treatment planning using combinations of different (AB) and identical diagnostic records (AA, BB).

	AB	AA	BB
Orthodontic postgraduates			
Mode	0.60	0.50	0.60
Median	0.60	0.65	0.60
Minimum	0.10	0.20	0.10
Maximum	1.00	1.00	1.00
Percentile (25)	0.40	0.50	0.50
Percentile (75)	0.70	0.80	0.78
Orthodontists			
Mode	0.75	0.75	0.50
Median	0.50	0.75	0.50
Minimum	0.00	0.00	0.00
Maximum	1.00	1.00	1.00
Percentile (25)	0.25	0.50	0.50
Percentile (75)	0.75	0.75	0.75

A, dental cast; B, dental cast + cephalometrics.

dental casts (P = 0.07) or cephalometric information in addition to the dental casts (P = 0.23) on the other. Consistency of treatment planning did not differ significantly (P = 0.47) between the use of only dental casts or with additional cephalometric information.

Discussion

The synthesis and interpretation of information from diagnostic records concerning a patient's malocclusion lead to orthodontic treatment planning. Each specific diagnostic record should give unique information about the characteristics of the malocclusion. However, a malocclusion is not a disease, is not a biologically abnormal state, and is not definable by a universally accepted gold standard (Vig and Dryland Vig, 1995). The optimal testing of a diagnostic record is to evaluate its consistency and validity. However, assessment of validity of a diagnostic record is not possible in the absence of the true state of disease. In studies where validity cannot be evaluated, comparison of consistency between diagnostic records is a valid alternative (Wenzel *et al.*, 2000; Ellis and Benson, 2003).

In this study, no difference was found between consistencies of orthodontic treatment planning with or without cephalometric information. Thus, cephalometrics as a diagnostic record does not seem to have an influence on orthodontic treatment planning of adolescents with a Class II division 1 malocclusion.

If the consistency of treatment planning using only dental casts had been 100 per cent, changes in decisions regarding orthodontic treatment planning after the addition of cephalometrics could be totally attributed to this radiographic addition. However, the consistency of orthodontic treatment planning on only dental casts was not 100 per cent. This inconsistency makes it difficult to assess the true contribution of cephalometrics to orthodontic treatment planning.

Unfortunately, comparison between different studies on consistency of orthodontic treatment planning is not possible, because consistency can only be compared within the same study (Wenzel *et al.*, 2000). Differences between investigations on consistency of orthodontic treatment planning might be based on the selection of cases, which might differ in the degree of deviation of particular aspects of a malocclusion from the ideal occlusion. Therefore, extrapolation to a broader spectrum of malocclusions of the statement that cephalometrics might not to be needed in orthodontic treatment planning is difficult, because patients with a specific malocclusion were selected in this study.

One might suspect that cephalometrics has a greater influence on orthodontic treatment planning of less experienced clinicians compared with more experienced clinicians. The statistical power to assess this potential difference was considered to be insufficient, because only four orthodontists and 10 orthodontic postgraduates formulated the treatment plans. The level of experience was of no importance in certain aspects of orthodontic diagnosis (Jonas, 1976; Kuyl *et al.*, 1994; Lau *et al.*, 1997). However, clinical experience might have an effect on treatment planning. Interestingly, this study found no influence of cephalometrics on orthodontic treatment planning. This absence of influence was found not only for orthodontists but also for orthodontic postgraduates. Extension of the current group of four orthodontists to a larger number in a future study would make assessment of the difference between clinicians with more and less experience possible.

In everyday practice, before starting treatment planning, a patient undergoes a clinical examination. Information on diagnostic records, such as dental casts and intra- and extra-oral photographs and radiographs, completes the information obtained during the examination and results eventually in an orthodontic treatment plan. In this study, only records of the patients were examined. However, some information was given at the start of the evaluation that might possibly be obtained during the clinical examination. Nevertheless, this relative lack of information might have influenced the consistency of treatment planning.

Ideally, panoramic and cephalometric radiographs should be taken, when information from the clinical examination is considered insufficient. Guidelines for orthodontic radiographs permit panoramic radiographs as part of an orthodontic assessment to determine the condition of the dentition and presence or absence of unerupted teeth (Isaacson and Thom, 2001). Cephalometric radiography is only justified if it directly influences information on (non-) radiographic records used for orthodontic treatment planning. Besides its role in orthodontic treatment planning, anatomical structures on cephalometric radiographs need to be interpreted for evidence of disease or injury (National Council on Radiation Protection and Measurements, 2003). Further utilization of cephalometric radiography has also been claimed as a screening tool to determine the need for a more rigorous ear–nose–throat follow-up concerning deviant measurements of adenoid size (Major *et al.*, 2006). Cephalometric radiographs might also be used for assessment of possible difficulty of attaining an ideal occlusion after specific orthodontic treatment, to assist in the location and assessment of unerupted, malformed, or misplaced teeth, and to identify optimal treatment timing in dentofacial orthopaedics using a modified version of the cervical vertebral maturation index (Pae *et al.*, 2001; Baccetti *et al.*, 2005). Limited serial cephalometric radiographs may help in the assessment of a trend in growth, or to monitor treatment changes (Isaacson and Thom, 2001).

The results of this study show that the effectiveness of cephalometrics as an additional orthodontic diagnostic record to plan orthodontic therapy is not proven. Despite the reduction in radiation dose over the past century, exposure to ionizing diagnostic radiation is hazardous and has biological risks (Farman, 2005). Individually based selection criteria for cephalometric radiography should be developed to reduce unproductive radiographs (Atchison *et al.*, 1991; Bruks *et al.*, 1999). Development of selection criteria remains difficult, because of the heterogeneous nature of orthodontic practice (Weintraub *et al.*, 1989). Clinicians tend to apply different criteria in terms of treatment planning (Ribarevski *et al.*, 1996). In mild cases of particular aspects of malocclusion, treatment decisions are less easily and universally made (Lee *et al.*, 1999). In these cases, i.e. borderline malocclusions, the use of therapeutic diagnosis might be a solution to reduce unproductive radiographs and thereby raise the effectiveness of cephalometrics (Isaacson and Thom, 2001). Therapeutic diagnosis is a procedure in which the response to an initial stage of treatment is used to confirm or modify the original treatment plan. Thus, the initial treatment is not based on cephalometrics, but on other diagnostic records. After initial treatment, a cephalometric radiograph might eventually be needed (Ackerman and Proffit, 1970).

A variety of alternative strategies remain for treatment of Class II division 1 malocclusions in growing children. Treatment planning decisions are entirely based on clinicians' preferences, which in turn are founded on the training of the clinician and/or cumulative subjective clinical impressions (Vig and Dryland Vig, 1995). This cumulative subjective clinical impression might never be overcome by additional cephalometrics. In that perspective, radiographs might be redundant and should not be taken on a routine basis.

Conclusion

Additional use of cephalometrics as a diagnostic record neither changed orthodontic treatment planning nor significantly influenced the level of consistency. Cephalometrics as a diagnostic record does not seem to have an influence on orthodontic treatment planning of adolescents with a Class II division 1 malocclusion.

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