TITLE

Associations of sagittal malocclusions with dental arch characteristics and crowding in Northern Finland Birth Cohort 1966

RUNNING TITLE

Associations of sagittal malocclusions

AUTHORS

Elisa Tervahauta[a], Jonna Nokela[b], Ville Vuollo[c], Pertti Pirttiniemi[d], Anna-Sofia Silvola[e]

[a] DDS, PhD student, Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Medical Research Center, Oulu University Hospital and University of Oulu, Oulu, Finland

[b] Dental student, Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Oulu, Finland

[c] Postdoctoral Researcher, Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Medical Research Center, Oulu University Hospital and University of Oulu, Oulu, Finland

[d] Professor and chair of Oral Development and Orthodontics, Leader of Unit of Oral Health Sciences, Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Medical Research Center, Oulu University Hospital and University of Oulu, Oulu, Finland

[e] Postdoctoral Researcher, Specialist in Orthodontics, Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Medical Research Center, Oulu University Hospital and University of Oulu, Oulu, Finland

CORRESPONDING AUTHOR

Elisa Tervahauta, Department of Oral Development and Orthodontics, Oral Health Sciences, Faculty of Medicine, University of Oulu, PO Box 5281, FI-90400 Oulu, Finland. E-mail: elisa.tervahauta@oulu.fi

AUTHOR CONTRIBUTION

ET contributed to the design of the study, measurements of the sagittal relationships, statistical analyses and writing of the manuscript. JN contributed to the measurements of the dental arch widths and lengths. VV contributed to the design of the study, the models of dental arch, gave statistical analysis guidance and revised the Materials and Methods section. PP contributed to the design of the study and revised the manuscript. ASS contributed to the design of the study, revised the manuscript, supervised and mentored ET.

CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

NFBC data is available from the University of Oulu, Infrastructure for Population Studies. Permission to use the data can be applied for research purposes via electronic material request portal. The use of data follows the EU general data protection regulation (679/2016) and Finnish Data Protection Act. The use of personal data is based on cohort participant's written informed consent at his/her latest follow-up study, which may cause limitations to its use. Please, contact NFBC project centre (NFBCprojectcenter@oulu.fi) and visit the cohort website (www.oulu.fi/nfbc) for more information.

ACKNOWLEDGMENTS

The authors thank the late professor Paula Rantakallio who launched of NFBC 1966, the participants of this study, and the work of the NFBC project centre.

ABSTRACT

Objective: To analyze the associations between the widths and forms of dental arches, malocclusions and crowding in middle-aged adult population.

Materials and Methods: The study material is part of the Northern Finland Birth Cohort 1966 (NFBC1966); the subjects were examined at the age of 46 years. A total of 781 adults with full dentition and no orthodontic treatment history were included. Overjet, overbite, cross-bite and scissor bite were examined during clinical examination. The widths and forms of dental arches, molar relationships and crowding were measured using three-dimensional (3D) dental models.

Results: Dental arches were significantly larger in males than in females. Class II (CII) occlusion and increased overjet (≥ 6 mm) were associated with narrow maxilla ($P < .001$, $P < .05$, respectively). Subjects with lateral cross-bite had significantly narrower maxilla and wider mandible ($P < .05$) than subjects with normal lateral occlusion. In subjects with CII occlusion, square or tapered maxilla and tapered or ovoid mandible were significantly more frequent compared to subjects with Class I (CI) occlusion ($P < .05$). CII occlusion was significantly associated with crowding in the maxilla ($P < .01$).

Conclusion: Narrow and tapered-shaped maxilla was related to CII occlusion, which was associated with dental crowding in the maxilla. Malocclusions were more likely to be found together with other malocclusions than alone.

KEY WORDS

Malocclusion; Dental arch; Crowding

1 | INTRODUCTION

The width and form of the dental arch is an essential element in orthodontics and crucial in orthodontic diagnostics, planning and therapy.[1] The size and shape of dental arches affect the space available, dental aesthetics, and the stability of the dentition.[2] The arch form evolves under the control of genetic factors and environmental impact.[3]

Considering the association between arch widths and sagittal relationships, narrow maxilla has been reported to be more prevalent in Class II (CII) occlusion compared to Class I (CI) occlusion.[4,5] However, earlier studies have offered contradictory findings about the possible differences in arch widths between CI occlusion and CII occlusion in mandible or between Class III (CIII) occlusion and CI occlusion.[4,6,7]

Chuck[8] classified arch forms as tapered, ovoid and square, and these terms are still commonly used by clinicians. Tapered form has previously been suggested as the most common arch form,[9] whereas others have reported that ovoid-shaped form dominates.[10,11] Furthermore, it has been examined that the arch form distribution between CI occlusion and CII occlusion was insignificant, but the difference within all three classifications was significant due to the high prevalence of the square form in CIII occlusion.[9]

Dental crowding is one of the most frequently confronted problems in orthodontics and it has been studied intensively from different perspectives. An earlier study in adolescents suggested that crowding may be associated more with dental arch widths than tooth sizes.[12] Although the changes in arch widths are small in adulthood,[13-15] crowding has been found to increase during lifetime.[16] There is a lack of knowledge in the literature on the association between crowding and dental arch widths in Caucasian adults. In addition, there is still a certain degree of controversy about the dental arch dimensions and only a few studies have evaluated how arch forms are associated with malocclusions, especially in adults. In most previous studies, at least part of the study population has been adolescents or young adults.[5-7,9,11,17]

The aim of the present study was to analyze the associations between the widths and forms of dental arches with malocclusion and crowding in adult population using population-based cohort data. The hypothesis is that the widths and forms of dental arches differ between malocclusion groups.

2 | MATERIALS AND METHODS

The data are part of an epidemiological and longitudinal research program, Northern Finland Birth Cohort 1966 (NFBC1966) (https://www.oulu.fi/nfbc/node/19663), which aims to promote health and well-being.[18] NFBC1966 originally included all live births in 1966 (n = 12,058) in the former provinces of Oulu and Lapland in Finland. The latest follow-up examination was in 2012 and 2013, when the cohort was 46 years old. A subgroup of 3,150 persons currently living in the Oulu region (range 100 km) was asked to attend; of those invited, 1,964 (62.3%) volunteered to take part in the examination including a clinical oral and dental health examination with occlusal assessment, three-dimension (3D) intra-oral scannings and questionnaire part. The subjects signed an informed consent form on their own behalf. The exclusion criteria in this study were the following: 1) refused to give their data for research; 2) missing 3D models; 3) missing data of clinical examination and/or questionnaire part; 4) missing permanent teeth or supernumerary teeth in the region of 16–26 and/or 36–46; 5) orthodontic treatment before or during the study. The flow chart of the final study population (n = 781) is presented in Figure 1. Subjects with missing permanent teeth or supernumerary teeth as well as subjects with orthodontic treatment history were excluded from this study due the detailed information of teeth loss or treatment method were not available. In addition, subgroup with teeth loss would have been too heterogeneous including inter alia caries, periodontitis, orthodontics or history of trauma. An orthodontic treatment usually affects the width and form of dental arch, and therefore the subjects with orthodontic treatment history were excluded as well. The research program is coordinated by the Department of Health Sciences, Faculty of Medicine, University of Oulu, and has been approved by the ethical committee of the Northern Ostrobothnia Hospital District (74/2011).

Subjects underwent standardized clinical oral and dental examinations performed by six calibrated dentists and a golden standard senior dentist at the Institute of Dentistry of the University of Oulu. All examiners were trained and calibrated both before and during the study to ensure the repeatability of the examinations. Occlusal registration was examined using the criteria developed by Björk et al.[19] and Harris and Corruccini[20]. Overjet and overbite were measured in maximal inter-cuspal position from the right central maxillary incisor with a manual scaler; the method is described in detail by Krooks et al.[21] Scissor bite was registered if the lingual cusp of one or more upper teeth occluded buccal to the opposing lower teeth. Lateral cross-bites were recorded if the buccal cusp of one or more upper teeth occluded lingual to the lower teeth.

The questionnaire contained questions concerning orthodontic treatment history before or after the age of 20. Answers were dichotomized as 0 = no orthodontic treatment, 1 = orthodontic treatment history.

2.1 | 3D Measurements

Intra-examiner reliabilities were measured with an interval of two weeks from 20 randomly selected 3D models before actual measurements. The repeated measurements in 3D models were compared using Cohen's kappa coefficient. The kappa scores for Angle classifications were 0.885 to 0.922 and were found to be at a good level. The 3D dental measurements using the same method have earlier been found to be excellent[22] and the accuracy of dental landmarks on 3D models to be reliable.[23]

The dental arches were digitized by using an iTero 3D scanner (Cadent, San Jose, CA, USA). Dental landmarks were positioned by Rapidform2006 (INUS Technology, Inc., Seoul, South Korea) and measurements were carried out with Matlab R2019b (MathWorks, Natick, Massachusetts). Occlusion plane was marked in the maxillary arch using four points: two points to the most incisal tip of the first incisors and two points to the tip of the mesiobuccal cusp of the first molars. All the mesial and distal contact points from the first molar to the first molar were marked for both arches. For each tooth, the midpoint of the mesial and distal contact point was computed. These midpoints and all the contact points were projected orthogonally on the occlusal plane. Using these projected points, the following measurements were measured:

1) The width of dental arches; the distance between the midpoints of the corresponding teeth on the right and left sides at different levels.

2) The maximal mesiodistal dimension of each tooth.

3) Dental arch length; the length from the distal point of the first molar to the distal point of the first molar on the opposite side of the dental arch along the incisal tip points.

The polynomial model proposed by Noroozi et al.[24] was fitted to these projected midpoints to model the dental arch. The least squares method was used for fitting the points of the maxillary and mandibular arch separately. The length and area of the dental arch were calculated using integration on the fitted polynomial function. To determine the shape of the arch, the ratio of arch area to the area of the rectangle computed by multiplying the depth by the width of the arch was calculated. This ratio varies between 0.5 and 1: a ratio close to 0.5 indicates a triangular arch while a ratio approaching 1 means a rectangular shape. This ratio was calculated for both arches of each subject and three shapes were defined with thresholds based on percentiles of ratio data. Ratio values below 15th percentile, values between 15th and 85th percentiles, and values above 85th percentile were classified as tapered, ovoid and square, respectively. These percentile thresholds were chosen to represent exceedingly tapered and square forms.

Crowding in the dental arch was analyzed as the sum of the size of each tooth minus the dental arch length in millimeters. The limit of crowing was considered to be 2 mm or more.

Sagittal relationships were determined from 3D models and divided using Angle's classification and half-cusp Class II or half-cusp Class III when the mesiobuccal cusp of the maxillary first molar sagittally coincided with the mesiobuccal cusp of the mandibular first molar:

1) Class I (CI): bilateral Class I, or Class I and half-cusp Class II
2) Class II (CII): bilateral Class II or half-cusp-Class II, or Class II and Class I / half-cusp Class II
3) Class III (CIII): bilateral Class III, or Class III and Class I / half-cusp Class III.

2.2 | Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics 25.0 with the significance level set as .05. Differences in dental arch widths between the gender and the malocclusions subgroups were analyzed by t-test or Mann-Whitney U-test, depending on normality. Decreased and increased overjet and overbite were compared separately to the scores of the normal occlusion group using Mann-Whitney U-test. Distributions of arch forms between malocclusion groups were compared with Fisher's exact test.

3 | RESULTS

Dental arches were significantly wider in males (*P* < .001) (Table 1). The maxillary inter-molar and inter-canine widths were significantly narrower in CII occlusion than in CI occlusion (*P* < .001). In the mandible, inter-canine width was significantly wider in CIII occlusion than CI occlusion (*P* = .037). Cross-bite was associated with narrower inter-molar and inter-canine widths in the maxilla (*P* < .001, *P* = .05, respectively) and wider inter-molar widths in the mandible than in subjects without cross-bite or scissor bite (*P* < .001). The width between second premolars in mandible was significantly narrower in subjects with scissor bite compared to subjects without cross-bite or scissor bite (*P* < .001).

Increased overjet (≥ 6) was associated with significantly narrower inter-molar (*P* = .033 all, *P* = .02 in males) and inter-canine (*P* = .022 all, *P* = .045 in males) widths in the maxilla (Table 2). In females, narrower maxillary inter-canine width was associated with overjet ≤ 0 (*P* < .003). In mandible, there were no significant differences in arch widths between categories of overjet.

In males, increased overbite was associated with narrower maxillary inter-molar and inter-canine widths (*P* = .002, *P* = .035, respectively) and decreased overbite with narrower maxillary inter-canine width (*P* = .004). In females, maxillary inter-canine width was significantly narrower in subjects with increased overbite (*P* = .05) compared to those with normal overbite. In mandible, inter-canine widths were significantly narrower in subjects with increased overbite than in the group with normal overbite (*P* = .022 all, *P* = .001 in males) (Table 3).

Tapered and square maxillary arch forms were more frequent in CII occlusion than in the subjects of CI occlusion (*P* = .038). In the mandible, there were more tapered and less square forms in CII occlusion compared to CI occlusion, (*P* < .001). Subjects with cross-bite were more likely to have tapered form of maxilla and tapered or ovoid form of mandible compared to subjects without cross-bite (*P* = .012, *P* = .003, respectively). Subjects with scissor bite had more often a square maxillary arch and tapered mandibular arch compared to subjects without scissor bite (*P* = .016, *P* < .001, respectively) (Table 4, Figure 2).

The maxilla was more crowded in the subjects of CII occlusion than in the subjects of CI occlusion (*P* < .001), In the mandible, subjects of CII occlusion had less crowding (*P* = .009) and subjects of CIII occlusion had more crowding (*P* = .006) compared to those with CI occlusion. In the maxilla, crowding was more common in the subjects with cross-bite ($P < .001$) and in the mandible, with scissor bite ($P < .001$) than in subjects with normal occlusion.

Tapered maxilla occurred more likely in crowded (23.0%) than in non-crowded (12.7%) dentitions, whereas square form was more frequent in non-crowded (16.0%) than in crowded (11.5%) dentitions. However, the most common form was ovoid form both in crowded (65.5%) and non-crowded (71.3%) dentitions. ($P = 0.002$). Inter-molar and inter-canine widths were significantly smaller in crowded than in non-crowded dentitions ($P < .001$).

4 | DISCUSSION

The present study aimed to examine the associations between the width and form of dental arches with crowding and malocclusions. The set hypotheses were partly verified, especially that of narrow and tapered-shaped maxilla being related to CII occlusion, increased overjet, cross-bite and crowding. Furthermore, crowding was generally more prevalent in adults with sagittal or transversal malocclusion.

The present findings showed that the maxilla was narrower in the subjects of CII occlusion than in CI occlusion, especially in the inter-molar region, which is in line with most of the earlier studies.[4,5,17,25] However, Uysal et al.[6] found that wider maxilla was more likely to associate with CII occlusion than CI occlusion. In the mandible, differences in arch widths between CI occlusion and CII occlusion were insignificant in the present study population. This is in line with the results of earlier studies on inter-molar width[17] or inter-canine width.[5,25] However, the latter studies found inter-molar width to be wider in CI occlusion than CII occlusion,[5,25] whereas Uysal et al.[6] found that CI occlusion was narrower than CII occlusion in both dimensions.

In the present study, there was a tendency for dental arches to be wider in CIII occlusion compared to CI occlusion, but the difference was statistically significant only in mandibular inter-canine width. The results of Uysal et al.[6] were consistent with results of this study only for the mandibular dimension. In contrast, their results were similar to those of Kuntz et al.[7], where the maxilla was found to be narrower in CIII occlusion compared to CI occlusion.[6,7]

Some of the earlier studies have examined CII division 1 (CII1) and division 2 (CII2) occlusions separately.[5,6,17,25] In the present study, they were examined as one group, CII occlusion, as comparisons with overjet and overbite in pre-analyses showed that the division between CII1 and CII2 occlusions was not clear or unequivocal.

The finding of the present study that males had significantly wider arches than females is confirmed by most of the earlier studies.[11,13,26,27] In this study, both genders had narrower maxillary arch widths in CII occlusion than CI occlusion.

For lateral cross-bite, narrow maxilla and wider mandible are very characteristic, and the present findings support this. In the present study, however, scissor bite was not significantly associated with arch widths.

The present study showed that arch forms in CII occlusion differed from CI occlusion in the maxilla, square form being more frequent than tapered in CII occlusion. This may be explained by the distal position of the mandible, which is why the dental arch can become wider in the anterior part of the maxilla. In the mandible, tapered form was more common than square form in CII occlusion. However, ovoid form was still most frequent in both arches, which is a general finding in most of the previous studies.[10,11] When exploring facial vertical proportion associated with arch form, previous studies have suggested that subjects with CI or CII occlusion tend to have narrower maxilla with increased sella-nasion – mandibular plane angle and concluded that dental arch width is associated with facial vertical morphology.[26,28]

The findings of this study of cross-bite and scissor bite support the clinical opinion on these malocclusions. Tapered maxilla was more likely to occur with cross-bite than without cross-bite, while ovoid form in the mandible was characteristic for the subjects with cross-bite. In subjects with scissor bite, square maxilla and tapered mandible were more prevalent than in subjects without scissor bite.

The present results confirm earlier findings that dental arches are associated with crowding.[7,12] In addition, the results of this study authenticated, that malocclusions seldom occur alone, but rather together with some other malocclusion. In subjects with CII occlusion and cross-bite, the maxilla was significantly more likely to be crowded than in those with Cl occlusion or without cross-bite. In the mandible, CIII occlusion and scissor bite were significantly associated with crowding. However, in CII occlusion, the mandible was less crowded than in CI occlusion.

The width and form of dental arches are significant factors in occlusion and associated with different malocclusion traits. Longitudinal studies have observed that from adolescence to adulthood, some changes still occur in transverse discrepancy.[14,15] Thus, it is important to get evidence of the relationships of malocclusions and arch widths also in adult populations. In future, studies regarding to etiology and genetics of dental arch forms at the population level would be valuable.

4.1 | Strengths and limitations of the present study

The strength of our study is a large data set and that the subjects were all born in the same year, and measurements were done using 3D models. However, a follow-up study over a longer period would certainly have provided better information.

5 | CONCLUSIONS

- Narrow and tapered-shaped maxilla is related to CII occlusion.
- CII occlusion is associated with dental crowding.
- Malocclusions are more likely to exist together with another malocclusion than alone.

REFERENCES

1. Ricketts RM. A detailed consideration of the line of occlusion. *Angle Orthod*. 1978;48(4):274-82.

2. Lee RT. Arch width and form: A review. *Am J Orthod Dentofacial Orthop*. 1999;115(3):305-313.

3. Cassidy KM, Harris EF, Tolley EA, Keim RG. Genetic influence on dental arch form in orthodontic patients. *Angle Orthod*. 1998;68:445–454.

4. Braun S, Hnat WP, Fender DE, Legan HL. The form of the human dental arch. *Angle Orthod*. 1998;68(1):29-36.

5. Huth J, Staley RN, Jacobs R, Bigelow H, Jakobsen J. Arch Widths in Class II-2 Adults Compared to Adults with Class II-1 and Normal Occlusion. *Angle Orthod*. 2007;77(5):837-44.

6. Uysal T, Memili B, Usumez S, Sari Z. Dental and alveolar arch widths in normal occlusion, Class II division 1 and Class II division 2. *Angle Orthod*. 2005;75:941–947.

7. Kuntz TR , Staley RN, Bigelow HF, Kremenak CR, Kohout FJ, Jakobsen JR. Arch Widths in Adults With Class I Crowded and Class III Malocclusions Compared With Normal Occlusions. *Angle Orthod*. 2008;78(4):597-603.

8. Chuck GC. Ideal arch form. *Angle Orthod*. 1932;4:312-327.

9. Olmez S, Dogan S. Comparison of the arch forms and dimensions in various malocclusions of the Turkish population. *Open Journal of Stomatology*. 2011;1:158-164.

10. Park SJ, Leesungbok R, Song JW, Chang SH, Lee SW, Ahn SJ. Analysis of dimensions and shapes of maxillary and mandibular dental arch in Korean young adults. *J Adv Prosthodont*. 2017;9(5):321-327.

11. Saeed HK, Mageet A. Dental Arch Dimensions and Form in a Sudanese Sample. *J Contemp Dent Pract*. 2018;19(10):1235-1241.

12. Howe RP, McNamara JA Jr, O'Connor KA. An examination of dental crowding and its relationship to tooth size and arch dimension. *Am J Orthod*. 1983;83(5):363-73.

13. Bishara SE, Jakobsen JR, Treder J, Nowak A. Arch width changes from 6 weeks to 45 years of age. *Am J Orthod Dentofacial Orthop*. 1997;111:401–409.

14. Tsiopas N, Nilner M, Bondemark L, Bjerklin K. A 40 years follow-up of dental arch dimensions and incisor irregularity in adults. *Eur J Orthod*. 2013;35(2):230-5.

15. Massaro C, Miranda F, Janson G, Rodrigues de Almeida R, Pinzan A, Martins DR et al. Maturational Changes of the Normal Occlusion: A 40-year Follow-Up. *Am J Orthod Dentofacial Orthop*. 2018;154(2):188-200.

16. Bishara SE, Treder JE, Damon P, Olsen M. Changes in the dental arches and dentition between 25 and 45 years of age. *Angle Orthod*. 1996;66(6):417-22.

17. Sayin MO, Türkkahraman H. Comparison of dental arch and alveolar widths of patients with Class II, Division 1 malocclusion and subjects with Class I ideal occlusion. *Angle Orthod*. 2004;74(3):356-60.

18. University of Oulu: Northern Finland Birth Cohort 1966. University of Oulu. http://urn.fi/urn:nbn:fi:att:bc1e5408-980e-4a62-b899-43bec3755243.

19. Björk A, Krebs AA, Solow B. A method for epidemiological registration of malocclusion. *Acta Odontologica Scandinavica*. 1964;22:27-41.

20. Harris EF, Corruccini RS. Quantification of dental occlusal variation: a review of methods. *Dent Anthropol*. 2008;21:1-11.

21. Krooks L, Pirttiniemi P, Kanavakis G, Lähdesmäki R. Prevalence of malocclusion traits and orthodontic treatment in a Finnish adult population. *Acta Odontologica Scandinavica*. 2016;74(5):362-7.

22. Kiviahde H, Bukovac L, Jussila P, Pesonen P, Sipilä K, Raustia A et al. Inter-arch digital model vs. manual cast measurements: Accuraty and reliability. *Cranio*. 2018;36(4):222-227.

23. Park J, Baumrind S, Curry S, Carlson SK, Boyd RL, Oh H. Reliability of 3D dental and skeletal landmarks on CBCT images. *Angle Orthod*. 2019;89(5):758–767.

24. Noroozi H, Nik TH, Saeeda R. The dental arch form revisited. *Angle Orthod*. 2001;71(5):386-9.

25. Staley RN, Stuntz WR, Peterson LC. A comparison of arch widths in adults with normal occlusion and adults with class II, Division 1 malocclusion. *Am J Orthod*. 1985;88(2):163-9.

26. Forster CM, Sunga E, Chung CH. Relationship between dental arch width and vertical facial morphology in untreated adults. *Eur J Orthod*. 2008;30(3):288-94.

27. Oliva B, Sferra S, Greco AL, Valente F, Grippaudo C. Three-dimensional analysis of dental arch forms in Italian population. *Prog Orthod.* 2018;19(1):34.

28. Grippaudo C, Oliva B, Greco AL, Sferra S, Deli R. Relationship between vertical facial patterns and dental arch form in class II malocclusion. *Prog Orthod*. 2013;14:43.

FIGURE LEGENDS

Figure 1. The flow chart of the study population.

Figure 2. Graphical illustration of arch form according to: A) Angle classifications; B) Lateral malocclusions; C) Tapered and square arch forms; D) Crowding.