Tampere University

HETTEL SEPP

Occlusal Traits, Orthodontic Treatment Need and Demand, and Mandibular Movement Capacity from Childhood to Adulthood in Estonia

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To Estonian children

ABSTRACT

Occlusal Traits, Orthodontic Treatment Need and Demand, and Mandibular Movement Capacity from Childhood to Adulthood in Estonia

Irregularity of teeth in children and young adults is associated with low oral health-related quality of life. As shown, orthodontic treatment can have a positive effect on oral health and quality of life. The aim of this cross-sectional study was to evaluate the prevalence and distribution of occlusal traits, mandibular movement capacity, and orthodontic treatment need in various stages of dental development in Estonian children and young adults.

The material included 1172 Estonians with deciduous, mixed, and permanent dentitions. Clinical registration of the inter- and intra-arch occlusal traits and mandibular movements was based on international standards and recommendations. Orthodontic treatment need and complexity were assessed from plaster casts using the Index of Complexity, Outcome and Need (ICON). Opinions regarding children's and young adults' general dental health, tooth alignment, dental appearance, and orthodontic treatment need were collected with questionnaires.

The prevalences of occlusal traits were in line with those reported in neighbouring countries Finland, Sweden and Latvia with some variation. The most prevalent occlusal trait in the deciduous, mixed, and permanent dentition was a canine class I sagittal relationship (70%, 74%, and 76%, respectively). Six percent, 27%, and 28% of individuals had increased ($\geq$ 3.5 mm) overjet and overbite in the deciduous, in mixed, and in permanent dentition, respectively. Posterior crossbite was observed in 18% in the deciduous, in 12% in the mixed, and in 30% in the permanent dentition. There was no crowding in the upper and lower arch in the deciduous dentition, but it occurred in 34% in the mixed dentition and in 51% in the permanent dentition. Midline diastema was observed in 68% in the deciduous, in 60% in the mixed, and in 11% in the permanent dentition. Between age groups, statistically significant differences were found in sagittal relationship, posterior and anterior crossbite, crowding, and midline diastema. Although asymmetrical canine and molar relationships were the most common findings in all dental stages, symmetry increased when age advanced.

Only a few (7 %) children with deciduous dentition had occlusal traits, indicating a favourable occlusal transition. According to ICON, 64 % of children with mixed dentition and 36 % of young adults with permanent dentition were in need of orthodontic treatment. Caregivers and young adults seemed to perceive occlusal traits and functions deviating from "normal". These highlighted traits were in line with those assessed by professionals.

Mandibular movement capacities were age and gender dependent. Maximum mouth opening, laterotrusion, and protrusion were related, and some occlusal traits, like crossbite, were associated with mandibular movements.

The data retrieved in this study provide the basis for the further planning and development of oral health care in Estonia.

Key words: association, ICON, jaw movement, occlusal trait, prevalence

TIIVISTELMÄ

Purennan piirteet, oikomishoidon tarve ja alaleuan liikelaajuus virolaislapsilla

Tavanomaisesta poikkeavien hampaiston piirteiden on todettu heikentävän lasten ja nuorten elämänlaatua, kun taas purentavirheiden hoidon on osoitettu parantavan heidän sosiaalisia suhteitaan ja itsetuntoaan. Tämän tutkimuksen tarkoituksena oli analysoida erilaisten purennan piirteiden esiintyvyyttä ja jakautumista, alaleuan liikelaajuutta sekä oikomishoidon tarvetta eri hampaiston kehitysvaiheissa olevilla virolaislapsilla.

Tutkimuksen aineisto koostui 1172 maitohammas-, vaihdunta- ja pysyvässä hampaiston kehitysvaiheessa olevasta lapsesta ja nuoresta. Hampaiden asentovirheet ja hammaskaarten väliset suhteet sekä alaleuan liikelaajuudet rekisteröitiin kliinisesti kansainvälisten käytäntöjen mukaisesti. Oikomishoidon tarve ja vaikeusaste arvioitiin kipsimalleilta käyttäen Index of Complexity, Outcome and Need (ICON) menetelmää. Huoltajien mielipiteet lasten hampaiden terveydestä, hampaiston ulkonäöstä ja oikomishoidon tarpeesta kerättiin kyselylomakkeella. Nuoret aikuiset täyttivät vastaavan lomakkeen.

Erilaisten purennan piirteiden esiintyvyys vastasi pienin poikkeuksin naapurimaissa Suomessa, Ruotsissa ja Latviassa raportoituja esiintyvyyksiä. Yleisin purennan piirre oli kulmahampaiden sagittaalisuhteen luokka I. Sen esiintyvyys oli maitohampaistossa 70 %, vaihduntavaiheessa 74 % ja pysyvässä hampaistossa 76 %. Suuren horisontaalisen ylipurennan (≥3.5 mm) esiintyvyys oli 6 % maitohampaistossa, 27 % vaihduntavaiheessa ja 28 % pysyvässä hampaistossa. Sivualueen ristipurentaa rekisteröitiin 18 %:ssa maitohampaistoista, 12 %:ssa vaihduntavaiheessa olevista ja 30 %:ssa pysyvistä hampaistoista. Maitohammasvaiheen hampaistoissa ei havaittu ahtautta sekä ylä- eikä alakaarella, mutta ahtautta havaittiin 34 %:ssa vaihduntavaiheen hampaistoista ja 51 %:ssa pysyvistä hampaistoista. Keskiviivan diasteemaa esiintyi 68 %:ssa maitohammasvaiheen hampaistoista, 60 %:ssa vaihduntavaiheen hampaistoista ja 11 %:ssa pysyvistä hampaistoista. Ikäryhmien välillä havaittiin tilastollisesti merkitseviä eroja sagittaalisuhteissa, etu- ja sivualueen ristipurennassa, hammaskaarten ahtaudessa sekä yläkaaren keskidiasteeman leveydessä. Vaikka molaari- ja kulmahammassuhteiden epäsymmetrisyys oli yleinen havainto kaikissa kehitysvaiheissa, symmetrisyys lisääntyi iän lisääntyessä.

Vain harvan maitohampaistovaiheessa olevan lapsen (7 %) purennan piirteet ennustivat suotuisaa vaihduntaa. ICON-hoidontarveindeksillä arvioituna oikomishoidon tarpeessa oli 64 % vaihduntavaiheen lapsista ja 36 % nuorista, joilla oli pysyvä hampaisto. Huoltajat ja nuoret aikuiset näyttivät havainnoivan purennan piirteitä ja toimintaa suhteessa ”normaaliin”. Havainnot olivat linjassa ammattilaisen tekemien ICON arvioiden kanssa.

Alaleuan liikelaajuudet olivat ikä- ja sukupuolisidonnaisia ja maksimaalisen avauksen, sivuliikkeiden ja protruusion liikelaajuuksien välillä oli riippuvuus. Eräät purennan piirteistä, kuten ristipurenta, olivat yhteydessä leuan liikelaajuuksiin.

Tämän tutkimuksen tulokset tarjoavat pohjan suun terveydenhuollon kehittämiselle Virossa.

Avainsanat: assosiaatio, ICON-hoidontarveindeksi, alaleuan liikelaajuus, purennan piirteet, prevalenssi

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ABBREVIATIONS

Class I	Cl I, canine or molar sagittal relationship
Class II	Cl II, canine or molar sagittal relationship
Class III	Cl III, canine or molar sagittal relationship
End to end	canine or molar sagittal relationship; incisal vertical or horizontal relationship; canine, premolar, or molar transversal relationship
ICON	Index of Complexity Outcome and Need
LMMl	lateral movement of the mandible to the left
LMMr	lateral movement of the mandible to the right
mm	millimetre
MMO	maximum mouth opening
OJ	overjet
OB	overbite
OHRQoL	Oral Health-Related Quality of Life
PMM	protrusive movement of the mandible
TMJ	temporomandibular joint
STUDY I	Group 1, deciduous dentition, 4–5-year-old children
STUDY II	Group 2, mixed dentition, 7–10-year-old children
STUDY III	Group 3, permanent dentition, 17–21-year-old young adults

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications.

I Sepp H, Saag M, Vinkka-Puhakka H, Svedström-Oristo AL, Peltomäki T. Occlusal traits of 4–5-year-old Estonians. Parents' perception of orthodontic treatment need and satisfaction with dental appearance. Clin Exp Dent Res. 2019 Jan 31;5(3):199-204

II Sepp H, Saag M, Svedström-Oristo AL, Peltomäki T, Vinkka-Puhakka H. Occlusal traits and orthodontic treatment need in 7- to 10-year-olds in Estonia. Clin Exp Dent Res. 2017 Apr 26;3(3):93-9

III Sepp H, Saag M, Peltomäki T, Vinkka-Puhakka H, Svedström-Oristo AL. Occlusal traits, orthodontic treatment need and treatment complexity among untreated 17–21-year-olds in Estonia. Acta Odontol Scand. 2019 Jan;77(1):44-8

IV Sepp H, Vinkka-Puhakka H, Peltomäki T. Mandibular movements in children with deciduous and mixed dentition and in young adults with permanent dentition-the association between movements and occlusal traits. Eur J Orthod. 2021 Jun 8;43(3):338-45

AUTHOR'S CONTRIBUTION

Hettel Sepp composed the study plan, prepared the documentation material, collected and analysed the study material, and wrote the articles.

1 INTRODUCTION

Orthodontic diagnoses do not manifest as major public health problems, like infectious disease, heart disease, or cancer, but the demand and need for orthodontic treatment has increased in recent years. Services required today differ from those available in the early 1970s, when the first epidemiological studies on the prevalence of occlusal traits and treatment need in the Nordic countries were published (Helm 1970, Myllärniemi 1970, Thilander and Myrberg 1973, Ingervall and Hedegaard 1975, Magnússon 1976).

In the dental literature, the position and malposition of teeth are described using several terms, each of them with continuous variations. The most commonly used term "malocclusion" has been replaced with "anomaly" (Helm 1970), "dentofacial traits" (Ackerman et al. 2007), "occlusal anomalies" (Laine and Hausen 1983, Murshid et al. 2010), "occlusal characteristics" (Kerosuo et al. 1991, Brunelle et al. 1996, Tschill et al. 1997, Mugonzibwa et al. 2004b, Ciuffolo et al. 2005, Tervahauta et al. 2022), "occlusal deviations" (Almeida et al. 2008), "occlusal features" (Foster and Menezes 1976), "occlusal traits" (Ciuffolo et al. 2005, Nguee et al. 2020, Madiraju et al. 2021), "occlusal variables" (Pahkala and Laine-Alava 2002), "occlusal variation" (Corruccini et al. 1990, El-Mangoury and Mostafa 1990), and "orthodontic variables" (Perillo et al. 2010). In Estonia, "malocclusion" is called an "anomaly of the dental and maxillofacial system".

"Occlusal traits" is a term to describe tooth positions and occlusion. This term does not define normality or abnormality and does not indicate the need for orthodontic treatment. The assessment of orthodontic treatment need is a complicated process in which occlusal traits are only one aspect. Patients and their caregivers often pay foremost attention to the position of the teeth, while dental professionals analyse also occlusal relationships in various jaw movements and the mobility of the lower jaw.

The prevalence of self-perceived and professionally assessed occlusal traits are population-specific and vary according to ethnicity (Kerosuo et al. 1991, Brunelle et al. 1996, Thilander et al. 2001, Josefsson et al. 2007). Not only secular trends but also different environmental exposures seem to influence the development of various occlusal traits (Kerosuo 2002, Clemente et al. 2021). Cultural norms influence patients' and their guardian's attitudes towards general and oral health (Adoga and Nimkur 2011, Kemoli et al. 2018, Chekenyere et al. 2020, Kemoli et al. 2022, Al-Turck et al. 2021, Rusly et al. 2022). Therefore, expected treatment need as well as seeking and receiving aesthetic dental treatment are also population-specific (Campos et al. 2022a). Services should be targeted to the population concerned (Linder-Aronson 1974, Shaw et al. 1995, Stenvik et al. 1997, Espeland and Stenvik 1999, de Oliveira 2003, Pietilä et al. 2009, Baelum et al. 2012, Benson et al. 2015, Öğütlü et al. 2018).

In Estonia, sufficient information on the prevalence of occlusal traits, the mobility of the lower jaw, and assessments of orthodontic treatment need are not available. In this cross-sectional study, occlusal traits were registered. In addition, mandibular movement capacity and orthodontic treatment need and demand were assessed in children in deciduous and mixed dentition, and in young adults in permanent dentition in Estonia.

The data retrieved in this study may help Estonian clinicians to estimate where an individual child stands compared to his/her age group, and it can also be used for treatment planning and the further development of oral health care in Estonia.

2 REVIEW OF THE LITERATURE

2.1 MORPHOLOGICAL VARIATIONS IN OCCLUSION

2.1.1 Terms and registration criteria

Several methods for the assessment and registration of occlusal traits for epidemiological studies have been devised (Björk et al. 1964, Ackerman and Proffit 1969, Baume and Maréchaux 1974, Foster and Menezes 1976, Bezroukov et al. 1979).

2.1.1.1 Occlusion

Occlusion denotes contacts between teeth and the way the same stimulus is interpreted by the brain (Michelotti et al. 2020, Pihut and Kulesa-Mrowiecka 2022). It also defines the dynamic interrelationship between facial structures (Thilander 2009). The masticatory system (composed of bones, joints, ligaments, teeth, muscles, and other soft tissues and nerves) is integrated with the central nervous system. Optimum orthopaedic stability in the masticatory system is important throughout the individual's lifetime for general health (Franco et al. 2012, Okeson 2015, Michelotti et al. 2020, Pihut and Kulesa-Mrowiecka 2022). According to Okeson (2015), optimum orthopaedic stability in the masticatory system follows when the mandibular condyles (centric relation) coincide with the maximum intercuspal positions (centric occlusion) of the teeth. Conditions that provide optimum orthopaedic stability in the masticatory system are well described by Okeson (2015).

2.1.1.2 Sagittal relationships of the first molars

Classification by Angle (1899) is based on the relationship of the buccal groove of the mandibular first permanent molar and the mesiobuccal cusp of the maxillary first permanent molar. Hence, Angle's classification determines the sagittal relationship of the first molars. For historical reasons, Angle's classification does not consider migrations or losses of teeth, functional parameters, the dental relationships related to facial beauty/harmony, or skeletal components that may vary from the ideal in all three dimensions, but it is still widely used (Feier et al. 2019).

In the literature, Angle's classification has been used for the registration of the anteroposterior relationship of the maxillary and mandibular first permanent molars (Ingervall and Hedegaard 1975, Lavelle 1976, Bezroukov et al. 1979, Laine and Hausen 1983, Hannuksela and Väänänen 1987, Ben-Bassat et al. 1997, Otuyemi and Abidoye 1993, Thilander et al. 2001, Behbehani et al. 2005, Jonsson et al. 2007, Josefsson et al. 2007, Borzabadi-Farahani et al. 2009, Lux et al. 2009, Dimberg et al. 2013), but also the anteroposterior relationship of the maxillary and mandibular first permanent molars with a mix of other occlusal traits/characteristics (Mills 1966, Grewe et al. 1968), such as the dental arch relationship (Rosenzweig 1961, Baume and Maréchaux 1974, Soh et al. 2005, Almeida et al. 2008, Komazaki et al. 2012) and the anteroposterior relationship of the maxilla and the mandible (Ast et al. 1965, Grabowski et al. 2007, Uslu et al. 2009).

Molar relationships have been scored in several ways: to the nearest quarter unit (Lux et al. 2009), to one-half cusp of the molar and more than one-half cusp of the molar (Ingervall and Hedegaard 1975, Bezroukov et al. 1979, Laine and Hausen 1983, Hannuksela and Väänänen 1987, Ben-Bassat et al. 1997, Behbehani et al. 2005, Borzabadi-Farahani et al. 2009, Mtaya et al. 2009, Dimberg et al. 2013, Steinmassl et al. 2017a, Elfseyie et al. 2020), more than one-half cusp of the molar (Lavelle 1976, Thilander et al. 2001, Madiraju et al. 2021), less than a full cusp and full cusp (Chung et al. 1971), and a full cusp width of the molar or more (Grewe et al. 1968, Myllärniemi 1970).

Mesial migration of the first molar due to the extraction of a deciduous molar has been both noted (Myllärniemi 1970, Thilander et al. 2001, Behbehani et al. 2005) and not taken into account (Bezroukov et al. 1979, Otuyemi and Abidoye 1993, Ben-Bassat et al. 1997).

Several terms have been used as a synonym for the class I molar relationship: Angle class I (Steinmassl et al. 2017a, Madiraju et al. 2021), neutral sagittal relationship (Kerosuo et al. 1991), neutroclusion (Chung et al. 1971), normal occlusion (Dimberg et al. 2013), and normal relation (Tervahauta et al. 2022). Respectively, the class II molar relationship has been called Angle class II (Steinmassl et al. 2017a, Madiraju et al. 2021), distal molar occlusion (Laine and Hausen 1983), distal occlusion (Kerosuo et al. 1991), distoclusion (Chung et al. 1971, Thilander et al. 2001, Grabowski et al. 2007), post-normal occlusion (Murshid et al. 2010, Dimberg et al. 2013), and post-normal relation (Leighton and Feasby 1988, Tervahauta et al. 2022). Synonyms for the class III molar relationship are Angle class III (Steinmassl et al. 2017a, Madiraju et al. 2021), mesial molar occlusion (Laine and Hausen 1983), mesial occlusion (Kerosuo et al. 1991), mesioclusion (Chung et al. 1971, Thilander et al. 2001), pre-normal occlusion (Murshid et al. 2010, Dimberg et al. 2013), and pre-normal relation (Leighton and Feasby 1988, Tervahauta et al. 2022).

2.1.1.3 Sagittal relationship of the deciduous second molars

The sagittal relationship of the deciduous second molars has been determined as perpendicular projections of the distal surfaces of the second molars to the occlusal plane (Thilander and Rönning 1985). Flush terminal plane is registered when the distal surfaces of the upper and lower second deciduous molars are in the same vertical plane in centric occlusion. The distal terminal plane is registered when the distal surface of the lower second deciduous molar is in the posterior position to the upper second deciduous molar. The mesial terminal plane is registered when the distal surface of the lower second deciduous molar is in an anterior relationship to the upper second deciduous molar (Onyeaso and Sote 2002, Abu Alhaija and Qudeimat 2003, Keski-Nisula et al. 2003, Berneburg et al. 2010, Shavi et al. 2015, Zhou et al. 2017, Kumar and Gurunathan 2019).

Values for terminal plane difference have been measured to 1 mm (Keski-Nisula et al. 2003), to 3–5 mm, 6–9 mm, and > 9 mm (Berneburg et al. 2010).

In the literature, terminologies for terminal planes also vary. Flush terminal plane: class I (Onyeaso and Sote 2002), flush type (Zhou et al. 2017), neutral occlusion (Berneburg et al. 2010), same vertical plane (Thilander and Rönning 1985), and straight terminal plane (Johannsdottir et al. 1997, da Silva and Gleiser 2008). Distal terminal plane: class II (Onyeaso and Sote 2002), distal step (Abu Alhaija and

Qudeimat 2003, Shavi et al. 2015, Fernandes et al. 2017, Kumar and Gurunathan 2019), distal type (Zhou et al. 2017), and distocclusion (Berneburg et al. 2010). Mesial terminal plane: class III (Onyeaso and Sote 2002), mesial step (Thilander and Rönning 1985, Abu Alhaija and Qudeimat 2003, Shavi et al. 2015, Fernandes et al. 2017, Kumar and Gurunathan 2019), mesial type (Zhou et al. 2017), and mesiocclusion (Berneburg et al. 2010).

2.1.1.4 Incisor relationships

Conventionally, incisor relationships have been registered in the horizontal and vertical plane (named overjet and overbite, respectively). Overjet has been measured as the horizontal distance between the most protruded upper central incisor and the labial surface of the corresponding mandibular incisor (Björk et al. 1964, Lavelle 1976, Bezroukov et al. 1979, Otuyemi and Abidoye 1993, Onyeaso and Sote 2002, Behbehani et al. 2005, Ciuffolo et al. 2005, Joseffson et al. 2007, Lux et al. 2009, Borzabadi-Farahani et al. 2009, Dimberg et al. 2015b, Steinmassl et al. 2017a, Yu et al. 2019, Elfseyie et al. 2020). In some studies, overjet is measured from the most labial point of the maxillary right central incisor to the corresponding point on the antagonistic mandibular incisor (Laine and Hausen 1983), or between the labial surface of the most anterior lower central incisor to the labial surface of the most anterior upper central incisor (Asiri et al. 2019). Measurements have also been made on the right side (Moorrees 1959, Keski-Nisula et al. 2003, Mugonzibwa et al. 2004b), but if the measurement was not possible on the right side, the left central incisor has been used (Brunelle et al. 1996, Perinetti et al. 2008). Overjet of all the maxillary and mandibular incisors have been measured by Saitoh et al. (2009).

Measurement accuracy varies from 1.0 mm (Bezroukov et al. 1979, Otuyemi and Abidoye 1993, Thilander et al. 2001, Almeida et al. 2008, Celikoglu et al. 2010) to 0.5 mm (Ben-Bassat et al. 1997, Behbehani et al. 2005, Grabowski et al. 2007, Borzabadi-Farahani et al. 2009, Lux et al. 2009, Dimberg et al. 2013) or 0.1 mm (Keski-Nisula et al. 2003). In some studies, in addition to the accuracy of 0.5 mm, overjet was assessed subjectively according to the British Standards Institute Incisor Classification of 1983 and scored class I, class II, or class III (Dahong et al. 2013).

Optimal/normal overjet has been given various threshold values: 0–2 mm (Onyeaso and Sote 2002), 0–3 mm (Brunelle et al. 1996, Madiraju et al. 2021), 0–4 mm (Perillo et al. 2010, Dimberg et al. 2013), 2–3 mm (Onyeaso 2004, Perinetti et al. 2008, Elfseyie et al. 2020), and 2–5 mm (Fatani et al. 2019). Overjet has been considered increased when over 2 mm (Onyeaso and Sote 2002, Grabowski et al. 2007), over 3.0 mm (Onyeaso 2004, Perinetti et al. 2008, Yu et al. 2019, Elfseyie et al. 2020), 3.5 mm (Madiraju et al. 2021), over 5 mm (Fatani et al. 2019), or over 4–6 mm (Dimberg et al. 2015b). Overjet more than 6 mm has been called extreme (Laine and Hausen 1983), severe (Murshid et al. 2010), and excessive (Dimberg et al. 2015b). Overjet less than 2 mm has often been considered decreased (Onyeaso 2004, Perinetti et al. 2008, Fatani et al. 2019, Elfseyie et al. 2020).

Overbite has been registered between the most overlapped incisors (Ingervall and Hedegaard 1975, Joseffson et al. 2007), or between the maxillary right central incisor. When the measurement has not been possible on the right central incisor, the left central incisor has been used (Mugonzibwa et al. 2004b, Perinetti et al. 2008, Asiri et al. 2019).

Measurement has been done in millimetres (Chung et al. 1971, Thilander et al. 2001, Keski-Nisula et al. 2003, Lux et al. 2009, Berneburg et al. 2010, Celikoglu et al. 2010, Jonsson et al. 2010, Elfseyie et al. 2020), or assessing subjectively the coverage of the mandibular incisor by the maxillary incisors (Bezroukov et al. 1979, Kerosuo et al. 1991, Otuyemi and Abidoye 1993, Farsi and Salama 1996, Onyeaso 2004, Behbehani et al. 2005, Bernabé et al. 2007, Perinetti et al. 2008, Borzabadi-Farahani et al. 2009, Dimberg et al. 2015b, Yu et al. 2019). Kerosuo et al. (1991) registered overbite in three categories: the maxillary incisor overlaps half of the crown height of the antagonistic mandibular incisor or less, an overlap of more than half but less than the total crown height of the mandibular incisor, and the total overlap of the incisor's mandibular incisors in contact with the palatal mucosa.

Overbite has been classified as optimal/normal at 0–4 mm (Perillo et al. 2010), 2–3 mm (Elfseyie et al. 2020), or up to a 1/3 overlap (Onyeaso 2004, Perinetti et al. 2008, Fatani et al. 2019, Madiraju et al. 2021); increased over 3 mm (Elfseyie et al. 2020) or when the mandibular incisors are in contact with the palatal mucosa (Abu Alhaija and Qudeimat 2003); a deep bite over 6 mm (Laine and Hausen 1983), over a 1/3 overlap (Perinetti et al. 2008, Dimberg et al. 2013, Fatani et al. 2019, Madiraju et al. 2021), over a 2/3 overlap (Grabowski et al. 2007, Dimberg et al. 2013, Yu et al. 2019), or the mandibular incisors are in contact with the palatal mucosa (Kerosuo et al. 1991); severe over 6 mm (Murshid et al. 2010); and excessive when the overlap exceeds the middle third of the crown of the mandibular central incisors (Onyeaso

2004). Overbite less than an incisal third of the crown has been considered reduced (Onyeaso 2004) and an overlap of 0 mm has been considered end to end (Grabowski et al. 2007, Fatani et al. 2019, Elfseyie et al. 2020).

Open bite has been named and registered as anterior open bite, negative overlap, and no vertical overlap when the anterior maxillary teeth do not cover the mandibular anterior teeth in the vertical plane (Lavelle 1976, Laine and Hausen 1983, Kerosuo et al. 1991, Hill 1992, Brunelle et al. 1996, Abu Alhaija and Qudeimat 2003, Grabowski et al. 2007, Dimberg et al. 2013, Proffit et al. 2013, Asiri et al. 2019, Fatani et al. 2019, Yu et al. 2019, Elfseyie et al. 2020). Open bite has been registered when negative overlap exceeds 1mm (Lavelle 1976) or ≥ 3mm (Hill 1992), or incisor contact is end to end (Laine and Hausen 1983). Open bite in the posterior area denotes a condition when there is a vertical space between one or more antagonistic posterior teeth (Laine and Hausen 1983, Cabrera et al. 2010, Elfseyie et al. 2020). Incomplete overbite has been used when the vertical overlap exists, but the mandibular incisors fail to contact either their antagonists or the palate (Smithpeter and Covell 2010). True open bite has been used when the mandibular incisors fail to contact their antagonists or the palate and there is no contact of the upper and lower incisors with excursive movements (Smithpeter and Covell 2010).

Open bite is also named apertognathia (Rijpstra and Lisson 2016).

2.1.1.5 Crossbite, scissor bite, spacing and crowding

According to Proffit et al. (2013) crossbite exists when the maxillary teeth are lingually positioned relative to the mandibular teeth. This can affect a single tooth or groups of teeth, involving the anterior teeth, posterior teeth, or both.

The slide between centric relation to the centric occlusion has been registered (Thilander and Myrberg 1973, Hannuksela and Väänänen 1987, Thilander et al. 2001, Dimberg et al. 2013), but not in most studies. In the occurrence of slide, crossbite has been called “anterior forward displacement”, “apparent crossbite”, “forced bite”, “forward disengagement”, “functional crossbite”, “functional protrusion”, “functional shift”, “lateral shift”, “mesial displacement”, “pseudo class III”, “pseudo-crossbite”, and “pseudo-mesiocclusion” (Thilander and Myrberg 1973, Dimberg et al. 2013, Wiedel and Bondemark 2015). In anterior crossbite with functional shift, inter-incisal contact is often possible when the mandible is in the centric relation.

Posterior crossbite has been registered when a buccal cusp of a maxillary tooth occludes lingually to the buccal cusp of the opposing mandibular tooth (Laine and Hausen 1983, Otuyemi and Abidoye 1993, Farsi and Salama 1996, Ben-Bassat et al. 1997, Mugonzibwa et al. 2004b, Perinetti et al. 2008, Borzabadi-Farahani et al. 2009, Jonsson et al. 2010), the upper molars occlude in a lingual relationship to the lower molars (Abu Alhaija and Qudeimat 2003, Yu et al. 2019), or the upper buccal cusps occlude to the fossa of the lower teeth (Fatani et al. 2019).

Posterior crossbite is also called "lingual crossbite" (Chung et al. 1971, Bezroukov et al. 1979, Brunelle et al. 1996, Ciuffolo et al. 2005, Komazaki et al. 2012, Elfseyie et al. 2020), and registered when a buccal cusp of a maxillary tooth occludes lingually to the buccal cusp of the opposing mandibular tooth (Chung et al. 1971, Bezroukov et al. 1979, Brunelle et al. 1996, Ciuffolo et al. 2005) or the palatal cusps of a maxillary tooth occlude buccally to the buccal surfaces of the corresponding mandibular tooth (Soh et al. 2005, Komazaki et al. 2012). This relationship is also called "scissor bite" (Bezroukov et al. 1979, Laine and Hausen 1983, Farsi and Salama 1996, Joseffson et al. 2007, Perinetti et al. 2008, Borzabadi-Farahani et al. 2009, Jonsson et al. 2010, Perillo et al. 2010), written also in the plural form as "scissors bite" (Helm 1970, Kerosuo et al. 1991, Dimberg et al. 2013, Yu et al. 2019) or with a hyphen as "scissors-bite" (Otuyemi and Abidoye 1993, Jonsson et al. 2010), and named also "buccal crossbite" (Chung et al. 1971, Bezroukov et al. 1979, Otuyemi and Abidoye 1993), "reversed cross-bite" (Helm 1970), or "facial crossbite" (Brunelle et al. 1996), and registered in the molar region (Farsi and Salama 1996) and the premolar and molar region (Chung et al. 1971, Laine and Hausen 1983, Kerosuo et al. 1991, Joseffson et al. 2007).

Posterior crossbite has been registered in the molar region only (Almeida et al. 2008, Yu et al. 2019) or in the premolar and molar regions (Chung et al. 1971, Laine and Hausen 1983, Otuyemi and Abidoye 1993, Ciuffolo et al. 2005, Joseffson et al. 2007, Borzabadi-Farahani et al. 2009, Komazaki et al. 2012). In some studies, it includes the dental arch from the canines to the premolars and molars (Ingervall and Hedegaard 1975, Lavelle 1976, Kerosuo et al. 1991, Farsi and Salama 1996, Bässler-Zeltmann et al. 1998, Soh et al. 2005, Perinetti et al. 2008) or at least one pair of the upper and lower teeth on the buccal segment occluding in the crossbite (Lavelle

1976, Kerosuo et al. 1991, Otuyemi and Abidoye 1993, Farsi and Salama 1996, Behbehani et al. 2005, Joseffson et al. 2007, Perinetti et al. 2008, Borzabadi-Farahani et al. 2009, Jonsson et al. 2010, Perillo et al. 2010, Dimberg et al. 2013, Asiri et al. 2019). Alternatively, either one pair of upper and lower teeth on each side or two pairs of upper and lower teeth on one side occlude in the crossbite (Brunelle et al. 1996) or in a cusp-to-cusp position transversally (Chung et al. 1971, Ben-Bassat et al. 1997, Perinetti et al. 2008, Borzabadi-Farahani et al. 2009, Elfseyie et al. 2020).

Some studies do not specify which variant of crossbite and/or scissor bite has been registered (Baume and Maréchaux 1974, Ben-Bassat et al. 1997, Thilander et al. 2001, Behbehani et al. 2005, Grabowski et al. 2007, Lux et al. 2009, Celikoglu et al. 2010, Jonsson et al. 2010, Dimberg et al. 2013, 2015b). Asiri et al. (2019) define posterior crossbite as facial or lingual displacement.

Anterior crossbite is also called "mandibular overjet" (Laine and Hausen 1983, Thilander et al. 2001, Ciuffolo et al. 2005, Zhou et al. 2017) and registered when any incisor occludes lingually or in an end-to-end position with the antagonistic mandibular teeth (Perinetti et al. 2008), between the maxillary and mandibular incisors region only (Farsi and Salama 1996, Behbehani et al. 2005, Dimberg et al. 2013), or including the canines (Thilander et al. 2001, Ciuffolo et al. 2005, Borzabadi-Farahani et al. 2009, Komazaki et al. 2012, Yu et al. 2019).

Anterior crossbite is registered when one or more of the maxillary incisors occlude lingual to the mandibular incisors (Kerosuo et al. 1991, Farsi and Salama 1996, Behbehani et al. 2005, Soh et al. 2005, Perinetti et al. 2008, Komazaki et al. 2012, Dimberg et al. 2015b, Wiedel and Bondemark 2015, Elfseyie et al. 2020), at least three upper incisors occlude lingual to the mandibular incisors (Myllärniemi 1970), or all four maxillary incisors occlude lingual to the mandibular incisors (Lavelle 1976, Thilander et al. 2001). Bässler-Zeltman et al. (1998) register anterior crossbite if one to three of the maxillary incisors occlude lingual to the mandibular incisors, but when four maxillary incisors occlude lingual to the mandibular incisors, they call the relationship "mandibular overjet". Teeth in an end-to-end position may be included in anterior crossbite (Magnússon 1976, Ben-Bassat et al. 1997) or not included (Myllärniemi 1970, Keski-Nisula et al. 2003, Komazaki et al. 2012).

Spacing is normal in the deciduous dentition with great individual variation (Moorrees 1959) and considered to be a requirement for proper alignment of the permanent teeth (Leighton 1969, Proffit et al. 2013). However, this theory has been questioned by Solow (1959). He has shown that the correlation of spacing of the deciduous dentition and space conditions of the permanent incisors' alignment is weak. No regression analyses can be found in the literature to describe the relationship between the spacing of the deciduous dentition and the alignment of the permanent incisors showing that the value of one can be predicted from the other one.

Spaces found in the deciduous dentition are called "interdental", "primate", and/or "Leeway" spaces (Moorrees 1959, Solow 1959, Proffit et al. 2013). Interdental spaces are also described as "developmental spaces" (Hughes et al. 2001), "physiological spaces" (Hughes et al. 2001), and "generalized spaces" (Abu Alhaija and Qudeimat 2003). Spaces are frequently seen between the anterior teeth, and less frequently between the molars (Moorrees 1959, Nyström and Ranta 1989, Hughes et al. 2001, Abu Alhaija and Qudeimat 2003).

Midline diastema (Perinetti et al. 2008, Perillo et al. 2010) is also called "medial diastema" (Kerosuo et al. 1991, Thilander et al. 2001), "central diastema" (Bässler-Zeltmann et al.1998), and "maxillary diastema" (Fatani et al. 2019), and it is recorded at the level of the papilla (Bässler-Zeltmann et al. 1998) and measured in millimetres (Kerosuo et al. 1991, Bässler-Zeltmann et al.1998, Ciuffolo et al. 2005) or scored subjectively as the space/gap between the maxillary or mandibular central incisors (Fatani et al. 2019). Midline diastema has been recorded as "present" when the distance between the maxillary central incisors is > 0 mm (Ribeiro et al. 2018), ≥ 1 mm (Onyeaso 2004, Perinetti et al. 2008), ≥2 mm or more (Bässler-Zeltmann et al.1998, Perillo et al. 2010), or > 2 mm (Kerosuo et al. 1991, Thilander et al. 2001, Ciuffolo et al. 2005, Dimberg et al. 2015b).

Teeth are crowded when they overlap or if there is insufficient space for the teeth to erupt without overlapping (Onyeaso 2004, Perinetti et al. 2008). According to Seeman et al. (2011), crowding is a result of contact point deviations, the malposition of the teeth, suprapositioned, supernumerary teeth, tooth rotation, and the restriction of supporting zones in the posterior region.

Crowding is also called "displacement of teeth" (Nguee et al. 2020), "irregularity of teeth" (Antoszewska-Smith et al. 2017), "imbrication" (Onyeaso and Sote 2002), "misalignment" (Ma et al. 2014), and "swarming" (Das et al. 2017).

Crowding can be measured with a dental calliper in millimetres directly in the mouth, in the plaster casts, and in digital models with digital techniques (Paredes et al. 2006, Sjögren et al. 2010, Alrasheed et al. 2022, Patano et al. 2023), and it can be estimated separately for the anterior and posterior segments of the maxillary and mandibular arches (Kerosuo et al. 1991).

Crowding has been registered by measuring mesiodistal crown widths of the canine, first and second premolar, and first molar and arch perimeter of both the maxillary and mandibular arch (Das et al. 2017) or the mesiodistal crown width of all teeth except the first, second, and third permanent molars, and also by arch perimeter analysis and Carey's analysis (Puri et al. 2007).

Crowding has been evaluated by Little's Irregularity Index (LII) (Little 1975, Antoszewska-Smith et al. 2017, Asiri et al. 2019, Patano et al. 2023), Tooth Size-Arch Length Discrepancy (TSALD) (Puri et al. 2007, Alrasheed et al. 2022, Patano et al. 2023), or Bolton's Indices (Anterior Bolton Index and Overall Bolton Index) (Paredes et al. 2006, Machado et al. 2020, Alrasheed et al. 2022). Other whole dental arch analyses are the widely used Bolton's simplified method (Pizzol et al. 2011) and Moyers' space analysis (Moyers 1973).

2.2 PREVALENCE OF OCCLUSAL TRAITS

The prevalence of occlusal traits in the deciduous, mixed, and permanent dentition in different countries is presented in Table 1 and Table 2.

Finnish children are more likely to have a class II sagittal canine and molar relationship and crowding than African children. African and Asian children have the highest prevalence of a class III sagittal relationship. When compared to other European, African, Middle Eastern, and Chinese children, Swedish children show a higher prevalence of open bite, and Austrian children show the highest prevalence of posterior crossbite compared to other European, African, and Asian children. Africans and Asians have a higher prevalence of spacing than Europeans (Kerosuo et al. 1991, Brunelle et al. 1996, Onyeaso and Sote 2002, Keski-Nisula et al. 2003, Mugonzibwa et al. 2004b, Lux et al. 2009, Seemann et al. 2011, Dimberg et al. 2013, Steinmassl et al. 2017a, Zhou et al. 2017, Yu et al. 2019, Madiraju et al 2021).

Table 1. Prevalence of occlusal traits in deciduous dentition in different countries.

			Deciduous canine sagittal relationship			Deciduous second molar sagittal relationship							
Country	Author	Age (Years)	Class I	Class II	Class III	Flush terminal plane	Mesial terminal plane	Distal terminal	Overjet > 4mm	Open bite	Posterior crossbite	Anterior crossbite	Scissor bite
CHN	Zhou et al. 2017	3–5	57.0	32.4	9.7	38.7	38.5	11.3	10.4		0.3	8.0	0.3
FIN	Keski-Nisula et al. 2003	4–7.8	46.1	52.4	1.5	47.8	19.1	33.1	26.7		7.5	2.2	1.1
FRA	Tscill et al. 1997	4–6								37.6**		7.2**	
GER	Berneburg et al. 2010	4–6	72.6	22.7	4.8	73.2	4.6	22.3			10.7		
IND	Kumar and Gurunathan 2019	3–6	27.0	12.0	61.0	36.0	56.0	8.0					
	Shavi et al. 2015	6	90.0	6.0	4.0	75.0	21.0	4.0					
JOR	Abu Alhaija and Qudeimat 2003	2.5–4	63.6	24.8	2.8	35.5	49.3	4.1		6.3	4.1		0.0
		5–6	52.2	32.4	4.3	38.1	46.5	3.3		5.2	9.1		
NIG	Onyeaso and Sote 2002	3–5	64.7	5.1	20.2	63.6	31.8	4.6		5.3	0.9	11.5	8.9
SWE	Dimberg et al. 2013	3–7	66.5	27.0	7.0				20.0	30.0	18.0	1.0	0.0

**Including end-to-end relationship.

Table 2. Prevalence of occlusal traits in mixed and permanent dentition in different countries.

Country	Authors	Age (Years)	First molar sagittal relationship Cl I	Cl II	Cl III	Overjet	Overbite	Open bite	Posterior crossbite	Anterior crossbite	Scissor bite	Midline diastema	Crowding
AT	Steinmassl et al. 2017a	8–10	64.3	33.1	2.5			0.0	15.3	14.6	1.9	38.9/ 17.2[m]	
CN	Yu et al. 2019	7–9	42.3	50.9	5.9			4.3[n]	2.6	10.5	1.0		
CO	Thilander et al. 2001	EMD LMD		20.4 24.9	3.9 3.5	23.1[d] 31.7[d]	17.4[d] 29.7[d]	11.4	4.0	4.9 6.2		13.5[a] 4.0[a]	50.6 55.7
DE	Lux et al. 2009	8.6–9.6		8.0-11.4	3.0			3.7[n]	5.9	4.3	0.2		
IT	Perinetti et al. 2008	7–11	46.8	16.8	6.3				14.3	8.2		28.8	
NL	Nguee et al. 2020	9.5–10.1				39.9[c]	22.7[c]	9.3	27.1	2.2			83.6
SA	Madiraju et al. 2021	8–9	75.2	23.4	1.4			4.3[i]	6.0	14.2		22.0	
SE	Dimberg et al. 2015b	7 11				3.7[e] 6.5[e]		9.6 0.4	18.0 5.1	1.5 0.4	0.0	6.5[a] 18.0[a]	31.0[a] 86.0[a]
US	Brunelle et al. 1996	8–11						1.9[n]	8.5	<1.0		19.3[a]	
CO	Thilander et al. 2001	PD		18.5	4.9	19.2[d]		8.7	3.9			3.7[&]	59.3
IR	Jamilian et al. 2014	15–17	65.2	24.1	10.7	22.7[d]	3.7	5.9	22.7			14.6	62.7
IT	Ciuffolo et al. 2005	11–14				19.1	41.0[b]		12.2	5.4		5.6	20.2
KW	Behbehani et al. 2005	13	36.1	56.2	7.7			3.4	25.2	20.8			73.2
MY	Elfseyie et al. 2020	18–25	39.3	12.0	48.7			4.7	12.1	7.3	7.8	15.7	75.9
SA	Fatani et al. 2019	12–15	52.3	25.0	20.5			3.3	22.3		2.5	22.0	74.0
US	Brunelle et al. 1996	12–17 18–50						1.0 1.0	7.9 9.9	<1.0 <1.0		4.8[a] 4.8[a]	

EMD–early mixed dentition; LMD–late mixed dentition; PD–permanent detention; [n]Negative vertical overlap; [i]Incomplete overbite; [m]Maxillary arch/mandibular arch; [a]> 2.0mm; [b]3.0mm; [c]≥ 3.5mm; [d]> 4.0mm; [e]> 6.0mm.

2.3 TRANSITION OF OCCLUSAL TRAITS

Data on the prevalence of occlusal traits help in planning therapeutic interventions. According to Dimberg et al. (2013), high rates of the spontaneous correction of anterior open bite, increased overjet and overbite, crossbite, and the establishment of new occlusal traits may occur during the transition from the deciduous to the early permanent dentition. Occlusal traits in the deciduous dentition may transfer to the mixed and permanent dentition (Stahl et al. 2003, 2007, Da Silva and Gleiser 2008, Seemann et al. 2011, Dimberg et al. 2013), and may need preventive and interceptive treatments (Kerosuo 2002, Stahl et al. 2003, 2007, Melink et al. 2010, Thilander and Bjerklin 2012, Kerosuo et al. 2013, Kemoli et al. 2018).

A class I canine relationship, flush terminal plane of the second molars, minimal overjet and overbite, and spacing are considered favorable for the proper transition to permanent dentition (Moorrees 1959, Solow 1959, Leighton 1975, Proffit et al. 2013). A symmetrical class I canine and first molar relationship, overjet, and overbite between 1–3 mm, without open bite, crowding, crossbite, and scissor bite would be optimal in the mixed and permanent dentition (Proffit et al. 2013).

The sagittal relationship of the permanent first molar is influenced by the terminal plane of the deciduous second molars (Horowitz and Hixon 1966, Bishara et al. 1988, Legovic and Mady 1999, Kirzioglu et al. 2013) and by the premature loss or massive caries of the deciduous molars (Perinetti et al. 2008). The reported transition of the flush terminal plane into a class I molar relationship varies from 37% to 89% (Bishara et al. 1988, Legovic and Mady 1999, Kirzioglu et al. 2013), and into a class II molar relationship from 10.5% to 44.0% (Bishara et al. 1998, Kirzioglu et al. 2013). A mesial terminal plane results more often in a class I than class II molar relationship (Kirzioglu et al. 2013). One per cent of children with a mesial terminal plane are at risk of developing a class III sagittal relationship (Thilander et al. 2001). The distal terminal plane in the deciduous dentition may in rare cases lead into a class I permanent molar relationship, but close to 100% into a class II molar relationship (Kirzioglu et al. 2013).

The aetiology of increased overjet, open bite, and crossbite may be related to oral habits such as finger, thumb, or pacifier sucking, and impaired nasal breathing caused by, for example, increased tonsils and adenoids or myofascial dysfunctions of the craniomandibular muscles. Therefore, it is important to pay attention to functional factors in early childhood (Stahl et al. 2007, Ovsenik 2009, Melink et al. 2010, Dimberg et al. 2013, Kirzioglu et al. 2013, Primožič et al. 2013).

Crossbite creates very much consideration in timing of treatment (Thilander and Lennartsson 2002, Melink et al. 2010, Primožič et al. 2013). Crossbite challenges clinician as a multifactorial problem, that may include skeletal asymmetry, dental arch asymmetry, occlusal interferences, TMD symptoms, neuromuscular disorders, or a combination of these (Agostino et al. 2014, Wiedel and Bondemark 2015, Ugolini et al. 2021, Myllymäki et al. 2023). The self-correction of posterior crossbite in transition from the deciduous into permanent dentition is possible (Melink et al. 2010, Dimberg et al. 2015b). However, research does not assess factors associated with the occurrence of self-correction of crossbite and does not allow to affirm how often the self-correction of posterior crossbite can occur. There is still a lot we don't know about self-correction of crossbite.

2.4 MANDIBULAR MOVEMENT CAPACITIES

Mandibular movement capacity (mouth opening, closing, lateral and protrusive movements) is an easy and important diagnostic reference for clinicians as a part of the examination of the stomatognathic system.

According to Woodford et al. (2020), techniques to measure mandibular motion can be classified into four categories: mechanical linkage systems, magnetic tracking systems, video motion analysis, and radiographic tracking. All these techniques are complex and rely on sophisticated machinery, even X-ray fluoroscopy, and therefore they are not clinically readily applicable. The clinical method widely used, which is reliable, simple, cheap, and quick, is the ruler and pencil method (Hirsch et al. 2006, Cortese et al. 2007, Okeson 2008, Karlo et al. 2010, Müller et al. 2013, Steinmassl et al. 2017b).

Mandibular movement capacity varies with the overall size of individuals, age, gender, joint condition, and the different chronicity and severity of diseases (Koob et al. 2005, Hirsch et al. 2006, Cortese et al. 2007, Okeson 2008, Scrivani et al. 2008, Müller et al. 2009, Sato et al. 2016, Li et al. 2017, de Souza et al. 2017, Starch-Jensen and Kjellerup 2017, Steinmassl et al. 2017b, Wu et al. 2017, Al-Ahmady et al. 2018,

Al-Nuumani et al. 2018, Hoverson et al. 2018, Savtekin and Sehirli 2018, Zhou et al. 2018). Some psychological conditions of an individual may also affect the stomatognathic system (Impellizzeri et al. 2019).
For the normal range of maximum mouth opening, Hirsch et al. (2006) suggest 50–52 mm in 10–17-year-olds and a value of 43 mm as the threshold for restricted maximum opening. For lateral and protrusive movements, the signs for restriction would be < 8 mm and < 5 mm, respectively. Okeson (2008) considers 53–58 mm as the normal range for mouth opening, less than 40 mm as restricted maximum opening, and < 8 mm as a sign of restricted lateral movements. Less than 40 mm MMO is considered restricted and a sign of temporomandibular involvement (Müller et al. 2009).

To the author's best knowledge, no literature exists about the association between mandibular movement capacities and occlusal traits or the correlations between movement capacities.

2.5 ORTHODONTIC TREATMENT NEED AND DEMAND

The effective management of any health problem requires data on how widespread the problem is in the population, what treatment is needed, and how much demand for treatment exists in the population. In orthodontics, not only health issues but also eating difficulties and self-perception of dental appearance influence the treatment demand. The essential goal in orthodontic treatment is good health. According to the World Dental Federation (FDI), "oral health is multifaceted and includes the ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex" [FDI's definition of oral health | FDI (fdiworlddental.org)].

Development of population-based health services should be based on data including individuals who seek or receive treatment as well as those who are left untreated (Helm 1970, Birkeland et al. 1996, Ng'ang'a et al. 1997, Stenvik et al. 1997, Espeland and Stenvik 1999, Thilander et al. 2001, Chew and Aw 2002, Mugonzibwa et al. 2004a, Ngom et al. 2007, Christopherson et al. 2009, Dias and Gleiser 2010). Several studies have shown that irregularity of teeth in children and young adults is associated with low oral health-related quality of life (OHRQoL – the term used when evaluating patient's perceptions of psychosocial well-being and oral health) (De Baets et al. 2012, Dimberg et al. 2015a, Alrashed and Alqerban 2021). Impacted teeth, increased overjet, crowding, and high orthodontic treatment need as well as age have the greatest negative impacts on OHRQoL (Kragt et al. 2016, 2017, Nguee et al. 2020).

On the other hand, orthodontic treatment can have a positive effect on OHRQoL (Locker and Allen 2007, Bernabé et al. 2008, Agou et al. 2011, Silvola et al. 2012, Javidi et al. 2017, Deng et al. 2018, Grewal et al. 2019, Peter et al. 2023). However, it has been debated whether quality-of-life questionnaires really measure the quality of life (Locker and Allen 2007, Campos et al. 2022b). Orthodontic treatment seems to reduce stress-related disorders, increase learning ability, and even improve memory (Ono et al. 2010, Weijenberg et al. 2011, Paganini-Hill et al. 2012, Teixeira et al. 2014).

In orthodontics, dental professionals deal and interact with genetic and environmental factors. These create developmental disorders in the craniofacial complex affecting oral function, breathing, phonetics, aesthetics, social interactions, and health-related quality of life (Proffit et al. 2013). Dealing with these disorders without appliances does not seem plausible in the close future. Orthodontic appliances have a negative impact on OHRQoL (Vidigal et al. 2022); therefore molecular biology might be a tool in future orthodontics (Grassia et al. 2018, Cultrera et al. 2022).

The timing of orthodontic treatment is under continuous discussion in orthodontic communities (Kluemper et al. 2000, Fleming 2017, Kirschneck et al. 2022, Fleming and Andrews 2023). However, a significant reduction in the need for orthodontic treatment in the permanent dentition following early treatment is well documented (Keski-Nisula et al 2003, Kerosuo et al. 2013, Schneider-Moser and Moser 2022). There are also arguments for traditional orthodontic treatment in the permanent dentition (Baccetti et al. 2012, Proffit et al. 2013, Hamidaddin 2023).

Attempts to assess orthodontic treatment need objectively have produced several orthodontic indices. Orthodontic treatment need indices have been widely used to screen patients to determine treatment priority and prevent unnecessary treatment. They provide a basis for discussion among health care professionals, patients, and

families as well. According to Shaw et al. (1995), orthodontic indices fall into the categories of the epidemiological, treatment need (treatment priority), treatment outcome, and treatment complexity.
Epidemiological indices record occlusal traits and estimate normality or abnormality in dental/occlusal development (Björk et al. 1964, Summers 1971, Baume and Maréchaux 1974, Little 1975). The Malocclusion Severity Index (MSI) (Hill 1992) was developed to establish the severity of abnormality of occlusal traits.

Treatment need indices mainly estimate treatment need in relation to an established list of morphological traits (professional assessment of occlusion) and functional or aesthetic components (based on how orthodontists graded dental appearance). The Dental Aesthetic Index (DAI) (Jenny et al. 1993) and Index of Orthodontic Treatment Need (IOTN) (Brook and Shaw 1989) are examples of treatment need indices with an assessment of dental aesthetics. The IOTN is used to assess residual treatment need following orthodontic treatment (Al Yami et al.1998, Svedström-Oristo et al. 2015). The Index of Complexity, Outcome, and Need (ICON) (Daniels and Richmond 2000) has been developed to assess various aspects of orthodontic treatment.

Treatment outcome indices assess the outcome and success of treatment. The Occlusal Index (Summers 1971) and Peer Assessment Rating Index (PAR) (Richmond et al. 1992a) are examples of outcome indices. The Occlusal Morphology and Function Index (OMFI) (Svedström-Oristo 2004) contains dental health components and functional features (contacts in the protrusion movement of the mandible and non-working-side contacts).

Newly developed indices tend to determine the treatment need in mixed dentition: these include the Index for Preventive and Interceptive Orthodontic Need (IPION) (Karaiskos et al. 2005); the Index of Orthognathic Functional Treatment Need (IOFTN) (Ireland et al. 2014), which assesses the functional need for orthognathic treatment; and the Prioritized Commitment-Based Clinical Assessment (PCCA), which assesses the success of treatment (Safavi et al. 2021).

Based on studies of validity and reproducibility, ICON, IOTN, PAR, OMFI, and the Summers' Occlusal Index have been shown to be both valid and reproducible (Richmond et al. 1992b, Shaw et al. 1995, Daniels and Richmond 2000, Svedström-

Oristo et al. 2002). As assessed with several treatment need indices, orthodontic treatment needs vary from 16.0% to 74.9% (Table 3).

Table 3. Orthodontic treatment need in different populations assessed with the IOTN, DAI, Swe NBH, and ICON.

Country	Age Years	Index	Orthodontic treatment need (%)	Author
Bangladesh	11–15	IOTN	50.9	Sultana and Hossain 2019
Brazil	12–13	DAI	50.3	Tessarollo et al. 2012
Colombia	5–17	Swe NBH	23.0 (urgent and great) 30.0 (moderate)	Thilander et al. 2001
France	9–12	IOTN	28.3 (great) 46.6 (borderline)	Souames et al. 2006
Germany	6–8	IOTN	26.2	Tausche et al. 2004
Iran	15–17	IOTN	9.0 (great need) 26.0 (borderline)	Jamilian et al. 2014
Italy	11–15	IOTN	59.5	Nobile et al. 2007
Jordan	12–14	IOTN	34.0	Abu Alhaija et al. 2004
Kenya	13–15	NOTI	29.0	Ng'ang'a et al. 1997
Lithuania	10–15 14–15	ICON	49.9 33.9	Baubiniene et al. 2009
Netherlands	9.5–10	IOTN	37.6 (great) 25.1 (borderline)	Nguee et al. 2020
Nigeria	12–18	ICON	38.1	Aikins et al. 2011
Norway	11	IOTN	26.2	Birkeland et al. 1996
Senegal	12–13	IOTN ICON	51.3 44.1	Ngom et al. 2007
Tanzania	3–5, 6–8, 9–11, 15–16	IOTN	16.0–36.0	Mugonzibwa et al. 2004a
Turkey	<18	ICON	35.0	Öğütlü et al. 2018
United Kingdom	11–12	IOTN	31.0	Burden and Holmes 1994
USA	8–11	IOTN	17.1 (great) 33.6 (borderline)	Christopherson et al. 2009

DAI, Dental Aesthetic Index; ICON, Index of Complexity, Outcome and Need; IOTN, Index of Orthodontic Treatment Need; NOTI, Need for Orthodontic

Treatment Index, Swe NBH, Treatment Priority Index of the Swedish National Board of Health and Welfare.

The main reasons to seek orthodontic treatment are dental appearance, attractiveness, social acceptance, and interactions, the prevention of bullying, improvements in masticatory function, and quality of life (Shaw 1981, Pietilä and Pietilä 1996, Birkeland et al. 1999, Josefsson et al. 2007, Nobile et al. 2007, Tessarollo et al. 2012, Livas and Delli 2013, Benson et al. 2015, Cai et al. 2018, Deng et al. 2018, Sultana and Hossain 2019, Bauss and Vassis 2023).

The goals of orthodontic treatment are good dentofacial function, aesthetics, health, and stability (Kerosuo et al. 2013, Andrews 2015). Patients have high expectations of the outcome of the orthodontic treatment (Birkeland et al. 1996). To achieve the best possible treatment results that meet the patients' expectations of a technically good result, interaction between the patient and personnel, and external and internal factors to the patient and treatment team are required (Bergkulla et al. 2017). Of these, "interaction and communication" at all stages of treatment seem to play a key role in achieving post-treatment satisfaction.

3 AIMS OF THE STUDY

General aim

The general aim of this thesis was to evaluate the prevalence and distribution of occlusal traits, mandibular movement capacity, and orthodontic treatment need and demand in Estonian children and young adults.

Specific aims

Occlusal traits (Studies I, II, III):

- to evaluate the distribution of occlusal traits in deciduous, mixed, and permanent dentitions.

Orthodontic treatment need, treatment demand, and satisfaction (Studies I, II, III):

- to study orthodontic treatment need, treatment demand, and satisfaction in deciduous, mixed, and permanent dentitions.

Mandibular movements (Study IV):

- to study the capacity of mandibular movements (maximum mouth opening, lateral and protrusive movements) in deciduous, mixed, and permanent dentitions;

- to investigate the influence of age and gender on mandibular movements;

- to analyse the association between mandibular movement capacity and occlusal traits.

4 HYPOTHESES OF THE STUDY

Morphological variation

- The prevalence and types of occlusal traits in Estonia do not significantly differ in deciduous, mixed, and permanent dentition from those of neighbouring countries in respective studies.

Mandibular movements

- The age and gender are associated with mandibular movement capacity.

Orthodontic treatment need

- Occlusal traits perceived by caregivers differ from those assessed by orthodontists.
- Self-perceived occlusal traits by young adults differ from those assessed by orthodontists.
- Objective and subjective treatment need are similar to those in neighbouring countries.

Mandibular movements and occlusal traits

- Correlations exist between mandibular movements.
- Associations exist between mandibular movement capacities and occlusal traits.

5 MATERIALS AND METHODS

5.1 MATERIALS

The recruitment of study subjects took place in randomly selected kindergartens and schools in Tallinn (North Estonia), Tartu (Central Estonia), and Pärnu (Southwest Estonia). A 95% confidence interval around an estimate (±2.5% of the estimate) was specified for the sample size calculation. In the sampling, a multistage stratified cluster design was implemented. The recruitment of subjects commenced in November 2009 and was completed in January 2012. The sample consisted of 1172 Estonians and is presented in Table 4.

Table 4. Distribution of children and young adults studied in the three regions of Estonia and the time interval of data collection.

Age group		Tallinn	Tartu	Pärnu	Total	Data collection
Study I: 4–5 years	Girls	61	65	64	190	03/2011–1/2012
	Boys	66	65	69	200	
	Total	127	130	133	390	
	N of kindergartens	5	4	2	11	
Study II: 7–10 years	Girls	63	65	70	198	11/2009–2/2010
	Boys	70	64	60	194	
	Total	133	129	130	392	
	N of schools	1	2	1	4	
Study III: 17–21 years	Girls	80	64	75	219	11/2009–1/2011
	Boys	44	72	55	171	
	Total	124	136	130	390	
	N of schools	1	2	1	4	

Prior to the study, a written description of the study protocol was given to all the children and their caregivers, and to the young adults. The children's parents/guardians and the young adults all signed an informed consent form. The study protocol was approved by the Ethics Review Committee on Human Research of the University of Tartu (Protocol No. 186T-24).

The initial number of subjects invited was 1512, but 340 subjects were excluded for the following reasons: 1) previous or current orthodontic treatment (n = 169), 2) caregivers did not agree to their child participating in the clinical study (n = 64), 3) the children were too afraid to participate in the clinical study (n = 62), 4) children were not in kindergarten on the examination day (n = 41), and 5) three children had a cleft lip and palate and one hemifacial microsomia. The sampling procedure is illustrated in Figure 1.

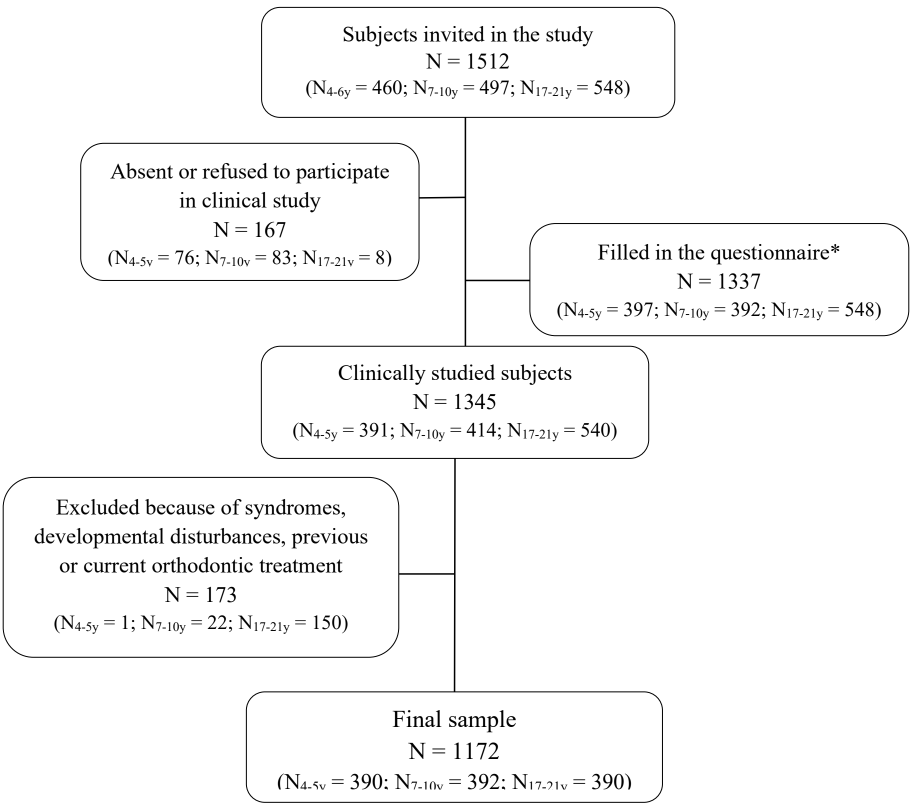

Figure 1. Inclusion process for the final study sample. *For age groups 4–5-years and 7–10-years, the questionnaire was filled by their caregivers.

5.2 METHODS

5.2.1 Clinical examinations

All clinical examinations were performed by one examiner (Examiner 1, HS). The examination of 4–5-year-old children was carried out at the kindergarten's medical office, while the examination of 7–10-year-old children and 17–21-year-old young adults was carried out in the school's dental office using a dental mirror, probe, pencil (0.3 mm), and millimetre ruler (Dentaurum 042-751 Münchner Modell).

The clinical study was complemented with alginate impressions from plaster casts and bite registration wax in centric occlusion for each participant. To obtain centric occlusion, the subject was asked to open his/her mouth slightly. The orthodontist gently verified that the mandible was relaxed, then the relaxed mandible was gently guided into centric occlusion to get indentations of the cusps of the lower teeth into pre-shaped softened registration wax.

5.2.2 Registration of the occlusal traits

Occlusal traits were registered clinically in centric occlusion. Registration of the occlusal traits was based on international standards (Moorrees 1959, Horowitz and Hixon 1966, Brunelle et al. 1996); a detailed description of the criteria is given in Appendix 1.

5.2.3 Registration of mandibular movements

Registration of the maximum mouth opening (MMO), lateral movement of the mandible to the right and left sides (LMMr, LMMl), and protrusive movement of the mandible (PMM) were registered.

Registration of mandibular movements was based on international standards and recommendations (Okeson 2008). Overbite and overjet were considered in the recording of MMO and PMM. The maximum opening and the lateral and protrusive movements of the mandible were repeated, and the mean of two measurements was used in the analyses. MMO, LMMr, and LMMl were measurable in all of the participants. PMM was measurable in 106 deciduous dentitions (27.2%) and in all mixed and permanent dentitions.

5.2.4 Determination of objective treatment need

Orthodontic treatment need and complexity were assessed by Examiner 1 and Examiner 2 from the plaster casts using the Index of Complexity, Outcome and Need (ICON) according to the written instructions (Daniels and Richmond 2000) (Appendix 2). A threshold score of more than 43 was used as an indication of treatment need. Scores < 29 indicated easy, 29–50 mild, 51–63 moderate, 64–77 difficult, and > 77 very difficult treatment complexity (Daniels and Richmond, 2000).

5.2.5 Questionnaire for determining treatment demand and satisfaction with dental appearance

Opinions regarding children's and young adults' general dental health, tooth alignment, dental appearance, and orthodontic treatment need were gathered with a questionnaire filled at home by caregivers of 4–5-year-olds and 7–10-year-olds, and by 17–21-year-olds at the dental office prior to the clinical examination. Multiple responses per question were allowed. Questions were modified for this study from a similar questionnaire (Pietilä and Pietilä 1996). The questionnaires for caregivers and young adults are given in Appendices 3 and 4, respectively.

5.3 STUDY I

5.3.1 Clinical examinations

The following occlusal traits were registered clinically by one orthodontist (Examiner 1) in centric occlusion: 1) bilateral sagittal relationships in deciduous canines and second molars, 2) overjet, 3) overbite, 4) crossbite, and 5) scissor bite.

5.3.2 Plaster casts

A total of 390 plaster casts were examined by Examiner 1 and Examiner 2 together registering five features in consensus: 1) class I, II, III, and end-to-end relationship of the deciduous canines; 2) distal, flush, and mesial terminal plane of the second molars separately for the right and left sides; 3) crowding; 4) diastemas between the central incisors; and 5) incomplete overbite.

5.3.3 Reliability

Twenty-two participants were examined twice within a one-week interval by Examiner 1. With a one-month interval, Examiner 2 re-registered six features on twenty plaster casts: 1) sagittal relationships in the deciduous canines, 2) sagittal relationships in the second molars bilaterally, 3) overjet, 4) overbite, 5) crowding, and 6) diastemas between the central incisors. The intra-examiner reliability and the inter-examiner reliability were very good ($r > 0.99$ and $r > 0.98$, respectively).

5.4 STUDY II and STUDY III

5.4.1 Clinical examinations

The following occlusal traits were registered clinically by Examiner 1 in centric occlusion: 1) bilateral sagittal relationships in the canines and first molars 2) overjet, 3) overbite, 4) crossbite, and 5) scissor bite.

5.4.2 Plaster casts

Four additional features were verified from the plaster casts: 1) bilateral sagittal relationship in the canines and first molars, 2) crowding, 3) diastemas between the central incisors, and 4) incomplete overbite. Examiner 1 assessed the plaster casts using ICON for orthodontic treatment need according to the written instructions (Daniels and Richmond 2000).

5.4.3 Reliability

Examiners 1 and 2 registered the following features from the 782 plaster casts in consensus: 1) bilateral sagittal relationship of the canines and first molars, 2) crowding, and 3) diastemas between the central incisors.

Twenty-two participants were re-examined one week after the initial examination by Examiner 1. With a one-month interval, Examiner 2 re-registered five features on twenty plaster casts: 1) bilateral sagittal relationships in the canines and first molars, 2) overjet, 3) overbite, 4) crowding, and 5) diastemas between the central incisors. The intra-examiner and inter-examiner reliability were very good ($r > 0.99$ and $r > 0.98$, respectively).

To assure the validity of ICON assessments, 78 (10.0%) randomly selected plaster casts were analysed by both Examiner 1 and by ICON-calibrated Examiner 3. The intra-examiner reliability was very good ($r > 0.97$). The inter-examiner reliability varied from moderate ($r = 0.5$) to good ($r > 0.93$).

5.5 STATISTICAL ANALYSES

The differences between categorical variables were examined with the Chi-square test or Fisher’s exact test where appropriate. For exploring gender differences in continuous variables, the t-test was used. To determine the association between risk factor and outcome, odds ratios with 95% confidence intervals were calculated. Pearson's and Spearman's correlations were used for reliability calculations and finding associations between mandibular movements. P-values < 0.05 were considered statistically significant. All data were analysed using IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.

6 RESULTS

6.1 STUDY I

6.1.1 Occlusal traits

6.1.1.1 Sagittal relationships

No statistically significant differences were found in the prevalence of occlusal traits between the genders ($p > 0.05$). The most prevalent occlusal traits were a class I sagittal relationship in the deciduous canines (69.7%) and midline diastema (67.7%) in both genders (Appendix 5). A combination of deciduous canine class I and a molar mesial terminal plane on the right and left sides occurred in 24.1% of children. A combination of deciduous canine class I on the right and left sides and molar flush terminal plane on the right and left sides occurred in 56 children (14.3%). All combinations of the deciduous canine and molar sagittal relationships in Study I are presented in Figure 2.

DECIDUOUS 2ND MOLAR left	DECIDUOUS CANINE left	DECIDUOUS 2ND MOLAR right: No molar					Distal terminal plane					Flush terminal plane					Mesial terminal plane				
	DECIDUOUS CANINE right	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III
No molar	No canine								1												
	Class I																				
	End to end																				
	Class II																				
	Class III																				
Distal terminal plane	No canine																				
	Class I							16	5				5					3	1		
	End to end						1		40	6			4	3				3	2		
	Class II								1	7				1							
	Class III								1										1		
Flush terminal plane	No canine																				
	Class I		1					5	6				56	3				13			
	End to end							1	7	1			13	17				7	3		
	Class II														1						
	Class III															1					
Mesial terminal plane	No canine																				
	Class I								3	3			11	2				94	8		1
	End to end									1			1	4				5	10		
	Class II																				
	Class III								2	1						1		2			5

Figure 2. Distribution of the sagittal relationships of the deciduous canine and second molars in 4–5-year-old children (n = 390). The x-axis shows the deciduous canine and second molar sagittal relationships on the right side of the child, and the y-axis shows the deciduous canine and second molar sagittal relationships on the left side of the child. The numbers inside the small squares indicate the number of children with the corresponding combination of deciduous canine and second molar sagittal relationship.

The most frequent sagittal relationship of the deciduous second molars was a mesial terminal plane on the right side (31.5%, n = 158) and on the left side (39.5%, n = 154), and a canine class I relationship on the right side (61.5%, n = 240) and on the left side (60.5%, n = 236). More detailed distributions of the sagittal relationships of the deciduous second molars and deciduous canines are presented in Appendices 6 and 7.

Both deciduous canine and molar sagittal relationships were symmetrical in 247 (63.3%) children. A symmetrical deciduous canine relationship was found in 305 (78.2%) children and a second deciduous molar relationship in 293 (75.1%) children. A symmetrical deciduous canine class I was combined with a symmetrical deciduous molar mesial terminal plane (n = 94, 38.1%), flush terminal plane (n = 56, 22.7%), and distal terminal plane (n = 16, 6.5%) (Table 5).

Table 5. Distribution of the symmetrical sagittal relationships of the deciduous canines and second molars (n = 247).

	Canine relationship							
	Class I (n = 166)		End to end (n = 67)		Class II (n = 8)		Class III (n = 6)	
	n	%	n	%	n	%	n	%
Distal terminal plane (n = 63)	16	6.5	40	16.2	7	2.8	0	-
Flush terminal plane (n = 75)	56	22.7	17	6.9	1	0.4	1	0.4
Mesial terminal plane (n = 109)	94	38.1	10	4.0	0	-	5	2.0

6.1.1.2 Overjet and overbite

The incisors were in contact in 62 (15.9%) children and in incomplete overbite in 319 (81.8%) children, while overjet was negative in 9 (2.3%) children. Both overjet and overbite were increased (≥ 3.5 mm) in 24 (6.2%) children, and negative in 6 (1.5%) children. Overjet was increased in 61 (15.6%) and overbite in 151 (28.7%) children. There were no gender differences for increased or negative overjet or overbite ($p > 0.05$).

6.1.1.3 Midline diastema and crowding

Midline diastema occurred in 265 (67.9%) children in the upper or lower arch. Midline diastema (mean 1.5 ± 0.9 mm) in the upper arch was present in 183 (46.9%) children, and in the lower arch (mean 1.1 ± 0.6 mm) in 217 (55.6%) children. There were no gender differences in midline diastemas or in crowding ($p > 0.05$).

6.1.1.4 Crossbite and scissor bite

Crossbite was found in 69 (17.7%) children and scissor bite in 13 (3.3%) children (Appendix 8). There were no gender differences in crossbite or scissor bite ($p > 0.05$).

6.1.1.5 Associations between occlusal traits

As a summary, in 7.2% of children the occlusal traits were of a favourable to optimal dental transition. Significantly more children with an asymmetrical deciduous canine or second molar relationship had crossbite compared to children with a symmetrical sagittal relationship ($p < 0.001$).

Among children with an asymmetrical end-to-end relationship in the canines, there were a statistically significantly higher proportion of children with crossbite compared to children with a symmetrical end-to-end relationship in the canines (15.4% vs 3.5%, respectively, $p = 0.013$). Among children with an asymmetrical deciduous second molar mesial terminal plane, there were a statistically significantly higher proportion of children with crossbite compared to children with a symmetrical deciduous second molar mesial terminal plane (21.0% vs 10.8% respectively, $p = 0.039$).

Among children with anterior crossbite, there was a statistically significantly higher proportion of children with a symmetrical or asymmetrical canine class III relationship (24.2% vs 2.0% respectively, $p < 0.001$) compared to children without anterior crossbite.

Among children with a symmetrical or asymmetrical distal terminal plane in the deciduous second molar, there was a statistically significantly higher proportion of children with increased overjet (≥ 3.5mm) ($p < 0.001$) compared to children with flush and mesial terminal planes.

6.1.2 Mandibular movements

The means of maximum mouth opening (MMO) and lateral right (LMMr), left (LMMl), and protrusive (PMM) movements were 43.6 mm, 9.5 mm, 9.4 mm, and 2.6 mm respectively. There were no gender differences in movements ($p > 0.05$) (Appendix 9). Lateral movements were strongly, positively correlated ($r = 0.830$, $p < 0.05$), MMO was weakly correlated with LMMr and LMMl ($r = 0.175$, $r = 0.213$, $p < 0.05$ respectively) (Appendix 10).

MMO was smaller in children with anterior and posterior crossbite and open bite compared to children without the corresponding traits ($p < 0.001$, $p = 0.002$, $p <$

0.001, respectively). MMO was larger in children with a deep bite and increased overjet compared to those without these traits ($p < 0.001$ and $p = 0.002$, respectively).

LMMr and LMMl were smaller in children with posterior crossbite ($p = 0.021$ and $p = 0.003$, respectively) and in children with anterior crossbite compared to those without these occlusal traits ($p < 0.05$ and $p < 0.05$, respectively) (Appendix 11).

6.1.3 Caregivers' perception of orthodontic treatment need and satisfaction with their child's dental appearance

There were more caregivers who were satisfied with the alignment of their child's teeth among those whose children did not have an asymmetrical sagittal relationship of the deciduous molars and canines, negative overbite or overjet, or scissor bite compared to caregivers whose child had these relationships ($p = 0.029$, $p = 0.010$, $p = 0.003$, $p = 0.029$ respectively). There were associations between caregivers' dissatisfaction with the child's teeth and occlusal traits (Table 6).

Table 6. Associations between caregivers' satisfaction with their child's teeth in relation to the professional assessment of occlusal traits (n = 390).

Professional assessment/Occlusal trait		Satisfaction with alignment of teeth: Dissatisfied n	Dissatisfied %	Satisfied n	Satisfied %	P
Asymmetrical sagittal relationship of molars and canines	No	8	2.2	125	34.2	**0.029**
	Yes	31	8.5	201	55.1	
Symmetrical sagittal relationship of molar and canine	No	36	9.9	294	80.5	1.000
	Yes	3	0.8	32	8.8	
Molar distal terminal plane	No	26	7.1	215	58.9	0.929
	Yes	13	3.6	111	30.4	
Molar mesial terminal plane	No	29	7.9	180	49.3	**0.022**
	Yes	10	2.7	146	40.0	
Molar flush terminal plane	No	19	5.2	173	47.4	0.607
	Yes	20	5.5	153	41.9	
Canine class I	No	12	3.3	99	27.1	0.959
	Yes	27	7.4	227	62.2	
Canine class II	No	38	10.4	308	84.4	0.706
	Yes	1	0.3	18	4.9	
Canine class III	No	35	9.6	316	86.6	0.051
	Yes	4	1.1	10	2.7	
Canine end to end	No	25	6.8	186	51.0	0.400
	Yes	14	3.8	140	38.4	
Overjet ≥ 3.5 mm	No	32	8.8	277	75.9	0.633
	Yes	7	1.9	49	13.4	
Overbite ≥ 3.5 mm	No	32	8.8	192	53.6	**0.005**
	Yes	7	1.9	134	36.7	
Negative overjet	No	35	9.6	321	87.9	**0.010**
	Yes	4	1.1	5	1.4	
Negative overbite	No	34	9.3	320	87.7	**0.003**
	Yes	5	1.4	6	1.6	
Crossbite	No	31	8.5	276	75.6	0.403
	Yes	8	2.2	50	13.7	
Scissor bite	No	35	9.6	318	87.1	**0.029**
	Yes	4	1.1	8	2.2	
Midline diastema	No	12	3.3	107	29.3	0.796
	Yes	27	7.4	219	60.0	

Bold–statistically significant ($p < 0.05$).

6.2 STUDY II

6.2.1 Occlusal traits

6.2.1.1 Sagittal relationships

Among the 392 participants, the most prevalent occlusal traits were a deciduous canine class I sagittal relationship (73.7%), midline diastema (73.0%), a first molar class I (57.4%) and first molar end-to-end (54.1%) sagittal relationship, and overbite ≥ 3.5 mm (51.8%). Girls had 1.6 (95% CI 1.1–2.4) times higher odds of crowding, and approximately two times lower odds for a deciduous canine end-to-end relationship, overjet ≥ 3.5 mm, and first molar class II compared to boys ($p < 0.05$) (Appendix 12).

The combination of canine and molar class I on the right and left side occurred in 95 (24.2%) children. The combination of canine class I on the right and left sides and end-to-end molar on the right and left sides occurred in 34 (8.7%) children. The detailed canine and molar sagittal relationships of children are presented in Figure 3.

		MOLAR right: No molar					Class I					Class II					Class III					End to end				
MOLAR left	**CANINE left** / **CANINE right**	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III
No molar	No canine																									
	Class I		2																							
	End to end																									
	Class II																									
	Class III																									
Class I	No canine						3	4				1		1								2	1	1		
	Class I						1	95	4				1	5	1						1	1	32	11		
	End to end							3	7					4									3	4		
	Class II									1																
	Class III							3			1												1			
Class II	No canine						2		1														2			
	Class I							2					6										1	1		
	End to end							3	1			2	1	13	2								1	1		
	Class II													4	1									1	1	
	Class III																									
Class III	No canine																1									
	Class I																									
	End to end							1																		
	Class II																									
	Class III							1													1					
End to end	No canine		1					1				1	1	2								3	5	2		
	Class I						1	6	1				1	14				1				4	34	14		
	End to end							7	3	1	1	1	1	5	1							2	9	24		
	Class II									1																
	Class III																									

Figure 3. Distribution of the sagittal relationships of the deciduous canine and first molars in 7–10-year-old children (n = 392). The x-axis shows deciduous canine and first molar sagittal relationships on the right side of the child, and the y-axis shows deciduous canine and first molar sagittal relationships on the left side of the child. The numbers inside the small squares indicate the number of children with the corresponding combinations of a deciduous canine and first molar sagittal relationship.

The most frequent sagittal relationship was a first molar end-to-end sagittal relationship on the right side (n = 161, 41.1%), class I on the left side (n = 192, 49.0%), and a deciduous canine class I relationship on the right side (n = 230, 58.7%) and the left side (n = 240, 61.2%). A more detailed distribution of the sagittal relationships of the canine and first molar is presented in Appendices 13 and 14. Both a deciduous canine and first molar sagittal relationship were symmetrical in 183 (46.7%) and asymmetrical in 70 (17.9%) children (Figure 4).

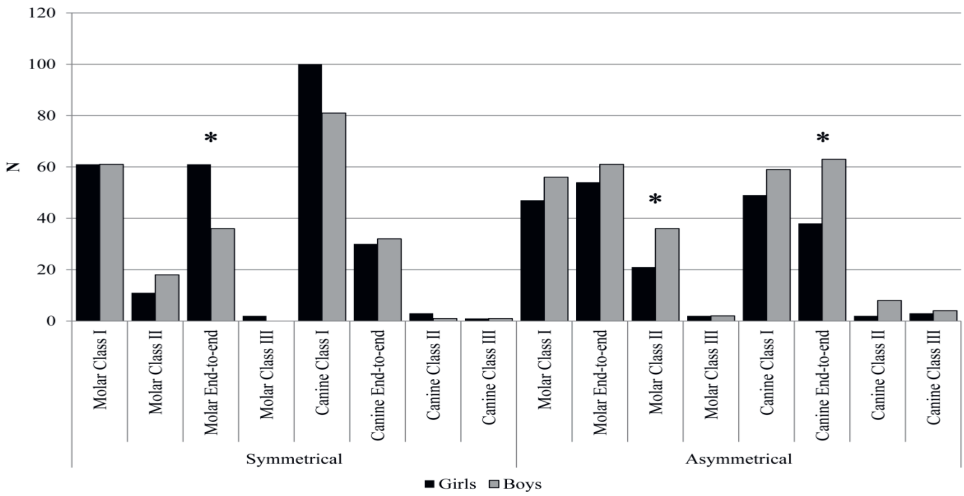

Figure 4. Distribution of symmetrical and asymmetrical sagittal relationships of the deciduous canines and first molars in 7–10-year-old children (n = 392). *Significant difference between girls (black) and boys (grey) ($p < 0.05$).

A symmetrical deciduous canine relationship was found in 249 (63.5%) and a symmetrical first molar relationship in 250 (63.8%) children. A symmetrical deciduous canine class I relationship was combined with symmetrical first molar class I (n = 95, 51.9%), first molar end-to-end (n = 34, 18.6%), and first molar class II relationships (n = 6, 3.3%) (Table 7).

Table 7. Combinations of the symmetrical sagittal relationships of the deciduous canines and first molars in 7–10-year-old children (n = 183).

	Canine relationships							
	Class I (n = 135)		End to end (n = 44)		Class II (n = 2)		Class III (n = 2)	
	n	%	n	%	n	%	n	%
Molar class I (n = 104)	95	51.9	7	3.8	1	0.5	1	0.5
Molar end to end (n = 58)	34	18.6	24	13.1	0	-	0	-
Molar class II (n = 20)	6	3.3	13	7.1	1	0.5	0	-
Molar class III (n = 1)	0	-	0	-	0	0.0	1	0.5

An asymmetrical deciduous canine and symmetrical first molar sagittal relationship was found in 140 (35.7%) and 130 (33.2%) children, respectively (Appendices 12 and 13). Statistically significantly more boys had an asymmetrical deciduous canine relationship or asymmetrical relationship both in the deciduous canines and first molars compared to girls ($p = 0.022$, $p < 0.001$, respectively).

6.2.1.2 Overjet and overbite

The incisors were in contact in 80 (20.4%) children, in incomplete overbite in 308 (78.6%) children, and overjet was negative in 4 (1.0%) children. Both overjet and overbite were increased (≥ 3.5 mm) in 107 (27.3%) children, and negative in 1 (0.3%) child. Increased overjet was present in 147 (37.5%) children and increased overbite in 203 (51.8%) children. Statistically significantly more boys had increased overjet compared to girls ($p = 0.019$). There were no gender differences in overbite ($p > 0.05$).

6.2.1.3 Midline diastema and crowding

Midline diastema was found in 234 (60.0%) children in the upper or lower arch. More than half of the children, 226 (57.7%), had midline diastema in the upper arch (mean 1.7 ± 0.8 mm) and 60 (15.3%) in the lower arch (mean 1.0 ± 0.7 mm). There were no gender differences in midline diastema ($p > 0.05$).

Crowding was found in 134 (34.2%) children in the upper or lower arch. Crowding was in the upper arch (mean 2.3 ± 1.5 mm) in 74 (18.9%) children and in the lower arch (mean 2.2 ± 1.5 mm) in 121 (30.9%) children. Girls had more crowding on the upper arch ($p = 0.049$).

6.2.1.4 Crossbite and scissor bite

Crossbite was found in 47 (12.0%) children and scissor bite in 6 (1.5%) children (Appendix 8). There were no gender differences in crowding or scissor bite ($p > 0.05$).

6.2.1.5 Associations between occlusal traits

Among children with a symmetrical or asymmetrical first molar/deciduous canine class II relationship, there was a statistically significantly higher proportion of children with increased overjet (≥ 3.5mm) (Table 8) and less crowding ($p < 0.05$) compared to children without a class II relationship. There were no children with a symmetrical or asymmetrical first molar class II relationship and posterior crossbite. In addition, there were no children with an asymmetrical deciduous canine class II relationship and crowding. Among children with an asymmetrical deciduous canine class III relationship, there was a statistically significantly higher proportion of children with posterior crossbite compared to children without a class III relationship (Appendix 15).

Table 8. Overjet in children with class I, end-to-end, class II, and class III sagittal relationships of the first molars and the deciduous canines in mixed dentition (7–10-year-old, n = 392).

	Molars				Canines			
	Class I	End to end	Class II	Class III	Class I	End to end	Class II	Class III
Overjet	(n = 225)	(n = 212)	(n = 86)	(n = 6)	(n = 73)	(n = 163)	(n = 14)	(n = 9)
< 0 mm	3	1	0	1	3	1	0	1
0.5–2.0 mm	99	65	17	4	122	34	0	5
0.5–3.0 mm	155	117	37	4	195	81	1	5
3.5–4.0 mm	42	57	21	0	60	39	4	0
> 4 mm	20	34	28	0	26	41	9	0

6.2.2 Mandibular movements

The means of MMO, LMMr, LMMl, and PMM movements were 49.2 mm, 11.3 mm, 10.8 mm, and 7.5 mm respectively. Boys had 1.15 (95% CI 1.06–1.26) times larger odds of protrusive movements than girls ($p < 0.05$) (Appendix 9). There was a strong positive correlation between LMMr and LMMl ($r = 0.625$, $p < 0.05$), while correlations between other mandibular movements were modest or weak ($p < 0.05$) (Appendix 10).

MMO was larger in children with a deep bite ($p < 0.001$) and smaller in children with an open bite ($p = 0.016$) compared to those without the same occlusal trait (Appendix 16).

6.2.3 Orthodontic treatment need and complexity of treatment

According to ICON, 64.3% of children needed orthodontic treatment. A total of 66.4% of caregivers felt that their child needed orthodontic treatment. A statistically significant association was found between the caregivers' desire to get a child's teeth straightened and the treatment need assessed using ICON ($\chi 2$ (1) = 5.59, $p = 0.022$).

6.2.4 Caregivers' perceptions of orthodontic treatment need and satisfaction with their child's dental appearance

The caregivers' and young adults' main expectations of orthodontic treatment were an improvement in dental appearance, ease of cleaning, improvement of function, and reduction in the risk of caries.

A significant number (169, 43.2%) of caregivers were dissatisfied with the appearance of their child's teeth. Caregivers whose child had deciduous canine class III, negative overjet, crossbite, or crowding were statistically more often dissatisfied ($p < 0.05$) (Table 9) than caregivers whose child did not have these traits.

Table 9. Associations between caregivers' satisfaction with their child's teeth in the professional assessment of occlusal traits (n = 392).

Professional assessment/Occlusal trait		Satisfaction with alignment of teeth				P
		Dissatisfied		Satisfied		
		n	%	n	%	
Asymmetrical sagittal relationship of molars and canines	No	131	35.8	167	45.6	0.523
	Yes	27	7.4	41	11.2	
Symmetrical sagittal relationship of molar and canine	No	84	23.0	111	30.3	0.970
	Yes	74	20.2	97	26.5	
Molar class I	No	70	19.1	86	23.5	0.571
	Yes	88	24.0	122	33.3	
Molar class II	No	122	33.3	164	44.8	0.708
	Yes	36	9.8	44	12.0	
Molar class III	No	153	41.8	207	56.6	0.089
	Yes	5	1.4	1	0.3	
Molar end to end	No	74	20.2	94	25.7	0.755
	Yes	84	23.0	114	31.1	
Canine class I	No	45	12.3	49	13.4	0.286
	Yes	113	30.9	159	43.4	
Canine class II	No	153	41.8	200	54.6	0.784
	Yes	5	1.4	8	2.2	
Canine class III	No	151	41.3	206	56.3	**0.043**
	Yes	7	1.9	2	0.5	
Canine end to end	No	99	27.0	116	31.7	0.185
	Yes	59	16.1	92	25.1	
Overjet ≥ 3.5 mm	No	94	25.7	137	37.4	0.211
	Yes	64	17.5	71	19.4	
Overbite ≥ 3.5 mm	No	82	22.4	98	26.8	0.365
	Yes	76	20.8	110	30.1	
Negative overjet	No	154	42.1	208	56.8	**0.034**
	Yes	4	1.1	0	0.0	
Negative overbite	No	155	42.3	205	56.0	1.000
	Yes	3	0.8	3	0.8	
Crossbite	No	130	35.5	191	52.2	**0.006**
	Yes	28	7.7	17	4.6	
Crowding	No	80	21.9	160	43.7	**< 0.001**
	Yes	78	21.3	48	13.1	
Scissor bite	No	156	42.6	205	56.0	1.000
	Yes	2	0.5	3	0.8	
Midline diastema	No	66	18.0	78	21.3	0.407
	Yes	92	25.1	130	35.5	

Bold–statistically significant ($p < 0.05$).

6.3 STUDY III

6.3.1 Occlusal traits

6.3.1.1 Sagittal relationships

Among the 390 young adults, the most prevalent occlusal traits were a class I sagittal relationship in the canines (76.1%) and in the first molars (70.6%), crowding (50.3%), overbite ≥ 3.5 mm (48.4%), overjet ≥ 3.5 mm (46.7%), and a canine end-to-end sagittal relationship (46.2%). Girls had 1.7 (95% CI 1.1–2.5) times greater odds of having a canine end-to-end relationship compared to boys ($p = 0.01$) (Appendix 17). A combination of canine and first molar class I on the right and left sides occurred in 126 (32.3%) young adults. The canine and first molar sagittal relationships in Study III are presented in Figure 5.

		MOLAR right																								
		No molar					Class I					Class II					Class III					End to end				
		CANINE right																								
MOLAR left	**CANINE left**	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III	No canine	Class I	End to end	Class II	Class III
No molar	No canine																									
	Class I		1								1															
	End to end																									
	Class II																									
	Class III																									
Class I	No canine																									
	Class I		2					126	12	1	3		1	5	4			2	2		2		3	22		
	End to end							16	7		1		2	2				4	2		1		1	3		
	Class II																									
	Class III										1										1					
Class II	No canine																									
	Class I												8	2	1						1		1	1		
	End to end							4	1				1	7	3	1							1			
	Class II							3	1					2	10			1						3		
	Class III																									1
Class III	No canine																				1					
	Class I							5	2					1				10	1		1			1		
	End to end																				1					
	Class II													1												
	Class III							1										3			4			1		
End to end	No canine																									
	Class I							3						3									5	1		
	End to end							22	4					17	2	1			2				2	12	1	
	Class II								1																	
	Class III																									

Figure 5. Distribution of the sagittal relationships of the canines and first molars in 17–21-year-old young adults (n = 390). The x-axis shows the canine and first molar sagittal relationships on the right side, and the y-axis shows the canine and first molar sagittal relationships on the left side. The numbers inside the small squares indicate the number of young adults with the corresponding combination of canine and first molar sagittal relationships.

The most frequent sagittal relationship was a first molar class I relationship on the right side (55.1%, n = 215) and on the left side (57.9%, n = 226), and a canine class I relationship on the right side (58.5%, n = 228) and on the left side (60.0%, n = 234). More detailed combinations of the sagittal relationship of the first molar and canine are presented in Appendices 18 and 19.

The canine and the first molar sagittal relationship were symmetrical in 190 (48.7%) and asymmetrical in 95 (24.4%) young adults (Figure 6). Girls had a statistically significantly less asymmetrical molar class III relationship (p = 0.003) and more canine end-to-end relationships compared to boys (p = 0.031).

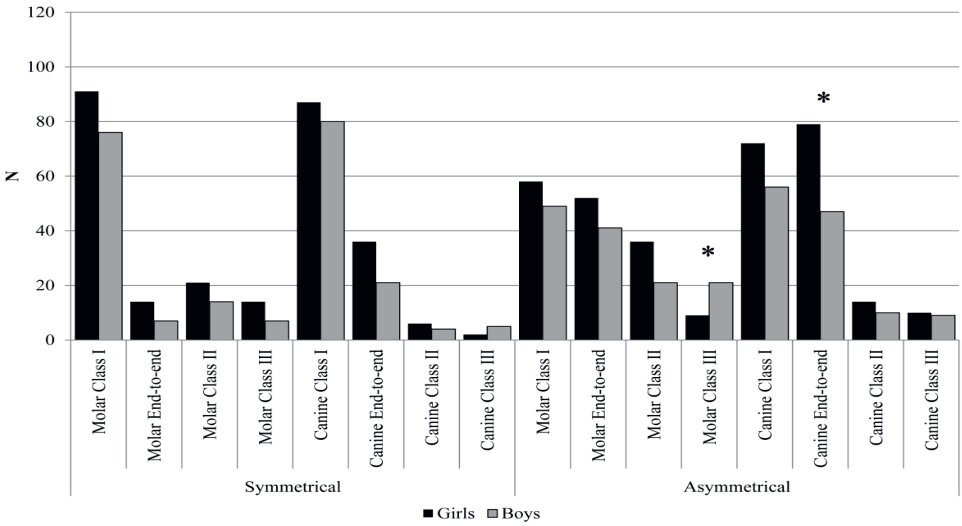

Figure 6. Distribution of the symmetrical and asymmetrical sagittal relationships of the first molars and canines in Study III (n = 390). *Statistically significant difference between girls (black) and boys (grey) ($p < 0.05$).

A symmetrical canine class I relationship was combined with a symmetrical first molar class I (n = 126, 66.3%), molar end-to-end (n = 5, 2.6%), first molar class II (n = 8, 4.2%), and first molar class III relationship (n = 10, 5.3%) (Table 10).

Table 10. Distribution of the symmetrical sagittal relationships of the canines and first molars in permanent dentition (17–21-year-old, n = 190).

	Canine relationship							
	Class I (n = 149)		End to end (n = 26)		Class II (n = 10)		Class III (n = 5)	
	n	%	n	%	n	%	n	%
Molar class I (n = 134)	126	66.3	7	3.7	0	-	1	0.5
Molar end to end (n = 17)	5	2.6	12	6.3	0	-	0	-
Molar class II (n = 25)	8	4.2	7	3.7	10	5.3	0	-
Molar class III (n = 14)	10	5.3	0	-	0	-	4	2.1

An asymmetrical canine relationship was found in 149 (38.2%) and a symmetrical first molar sagittal relationship in 145 (37.2%) young adults (Appendices 18 and 19). There was no gender difference in canine and first molar relationships ($p > 0.05$).

6.3.1.2 Overjet and overbite

The incisors were in contact in 291 (74.6%) and in incomplete overbite in 99 (25.4%) young adults, and overjet was negative in 2 (0.5%) young adults. Both, overjet and overbite were increased ($\geq$ 3.5 mm) in 108 (27.7%) young adults. Overjet was increased in 183 (46.9%) and overbite in 188 (48.2%) young adults. No gender difference was found in increased overjet or overbite ($p > 0.05$).

6.3.1.3 Midline diastema and crowding

Midline diastema occurred in 39 (10.5%) young adults in the upper or lower arch. Midline diastema was present in 35 (9.0%) young adults in the upper arch (mean 1.1 $\pm$ 0.6) and in 11 (3.0%) young adults in the lower arch (mean 1.1 $\pm$ 0.3 mm).

Crowding occurred in 200 (51.3%) young adults in the upper or lower arch. Crowding in the upper arch (mean 1.4 $\pm$ 1.3mm) was present in 114 (29.2%) young adults, and in the lower arch (mean 1.8 $\pm$ 1.2 mm) in 181 (46.4%) young adults. No gender difference was found in crowding ($p > 0.05$).

6.3.1.4 Crossbite and scissor bite

Crossbite was found in 116 (29.7%) young adults, and a scissor bite in 10 (2.6%) young adults. There was no gender difference in crossbite or scissor bite ($p > 0.05$) (Appendix 8).

6.3.1.5 Associations between occlusal traits

A statistically significantly higher proportion of young adults with a symmetrical or asymmetrical canine or first molar class II relationship had increased overjet (OJ $\geq$

3.5mm) (Table 11), scissor bite, and a statistically significantly smaller proportion had a posterior crossbite ($p < 0.05$). A statistically significantly higher proportion of young adults with a symmetrical or asymmetrical canine or first molar class III relationship had an anterior crossbite and posterior crossbite ($p < 0.05$). A statistically significantly higher proportion of young adults with increased overjet (OJ ≥ 3.5 mm) had an increased overbite (OB ≥ 3.5mm) ($p < 0.05$). A statistically significantly higher proportion of young adults with scissor bite had increased overjet (OJ ≥ 3.5mm) ($p < 0.05$) compared to those without scissor bite (Appendix 15).

Table 11. Overjet in young adults with class I, end-to-end, class II, and class III sagittal relationships of the first molars and canines in Study III (17–21-year-old, n = 390).

	Canine relationship							
	Class I (n = 149)		End to end (n = 26)		Class II (n = 10)		Class III (n = 5)	
	n	%	n	%	n	%	n	%
Molar class I (n = 134)	126	66.3	7	3.7	0	-	1	0.5
Molar end to end (n = 17)	5	2.6	12	6.3	0	-	0	-
Molar class II (n = 25)	8	4.2	7	3.7	10	5.3	0	-
Molar class III (n = 14)	10	5.3	0	-	0	-	4	2.1

6.3.2 Mandibular movements

The means of MMO, LMMr, LMMl, and PMM movements were 54.3 mm, 11.6 mm, 11.6 mm, and 8.6 mm, respectively. Compared to females, males had 1.11 (95% CI 1.07–1.15) times greater odds of MMO, 1.11 (95% CI 1.02–1.21) times greater odds of LMMr, 1.19 (95% CI 1.08–1.31) times greater odds of LMMl, and 1.15 (95% CI 1.05–1.25) times greater odds of PMM (Appendix 9). There was a strong correlation between LMMr and LMMl ($r = 0.759$, $p < 0.05$) and a moderate correlation between other mandibular movements (Appendix 10).

PMM was larger in young adults with scissor bite and with increased overjet (≥ 3.5 mm) ($p = 0.007$ and $p < 0.001$, respectively) compared with those without the corresponding occlusal trait (Appendix 20).

6.3.3 Orthodontic treatment need and complexity of treatment

Assessed using ICON, 36.0% of young adults needed orthodontic treatment. A total of 44.4% of the young adults felt that they needed orthodontic treatment. A statistically significant association was found between young adults' desire to get their teeth straightened and the orthodontic treatment need assessed using ICON ($\chi 2$ (3) = 19.33, $p = 0.000$). Opinions regarding orthodontic treatment need did not differ between genders ($\chi 2$ (3) = 3.76, $p = 0.288$).

6.3.4 Young adults' perception of orthodontic treatment need and satisfaction with dental appearance

The majority of young adults were satisfied with the dental health and appearance of their teeth (n = 276, 70.1%). Those young adults dissatisfied with their dental health and alignment of teeth numbered 83 (21.3%). Satisfied young adults had less crowding in the lower arch compared to those who were dissatisfied (0.72 vs 1.1, $t(366) = -2.57$, $p = 0.011$), and the amount of crowding in the upper arch was substantially less than among the dissatisfied participants (0.32 vs 0.73, t(366) = -2,87, $p = 0.005$). Dissatisfied young adults had more often increased overjet (OJ ≥ 3.5 mm) than those who were satisfied ($T(366) = -4.46$, $p < 0.001$).

6.4 COMPARISON OF FINDINGS BETWEEN DIFFERENT AGE GROUPS

6.4.1 Occlusal traits

The prevalence of occlusal traits in Study I, Study II, and Study III are presented in Figure 7.

In the present study, a deciduous canine class I relationship occurred in 73.7% of mixed dentition children, 16.3% more often compared to the first molar class I relationship. A canine class I relationship occurred in 76.0% of young adults, 6.0% more often than the class I relationship of the first molar.

An asymmetrical sagittal relationship was statistically significantly more frequent in Study II and Study III than in Study I (53.5% vs 51.3% vs 36.7% respectively, $p < 0.001$). Crowding was most frequent in Study III, less frequent in Study II, and there was no crowding in Study I ($p < 0.05$). The majority of 4–5-year-old and 7–10-year-old children (67.7% and 59.7%), and some (10.5%) young adults had midline diastema. Posterior and anterior crossbite were statistically significantly less frequent in Study II than in Study I and Study III ($p < 0.05$). Open bite was rare in all age groups. Additionally, anterior crossbite and scissor bite were rare at all ages.

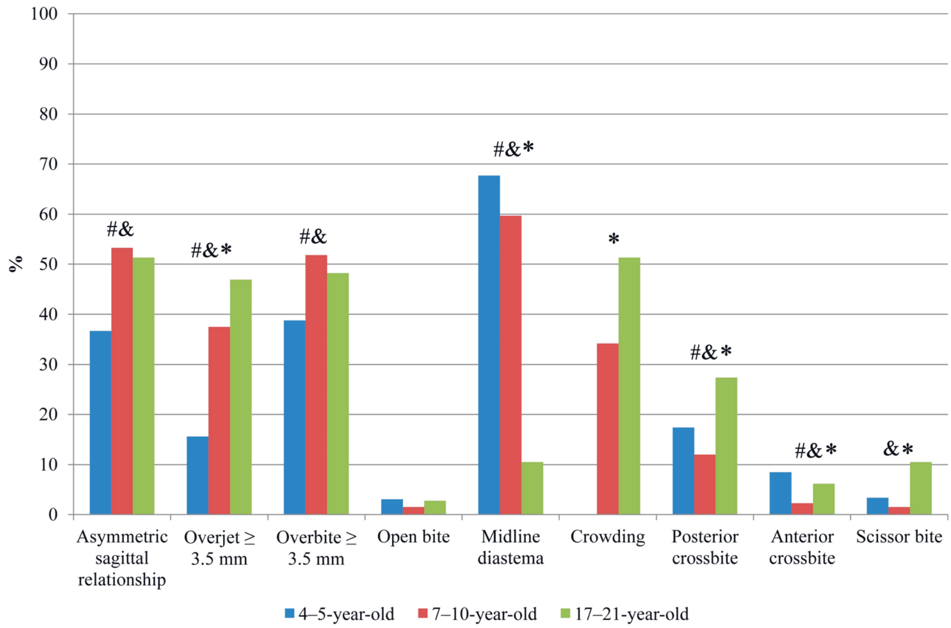

Figure 7. Prevalence of occlusal traits in Studies I, II, and III. #A statistically significant difference existed between Study I and II ($p < 0.05$); &A statistically significant difference existed between Study I and III ($p < 0.05$); *A statistically significant difference existed between Studies II and III ($p < 0.05$).

Statistically significantly more young adults had crowding in the upper dental arch compared to 7–10-year-old children (29.2% vs 18.9%, $p = 0.001$). In addition, statistically significantly more young adults had crowding in the lower dental arch compared to 7–10-year-old children (45.9% vs 31.4%, $p < 0.001$) (Figure 8).

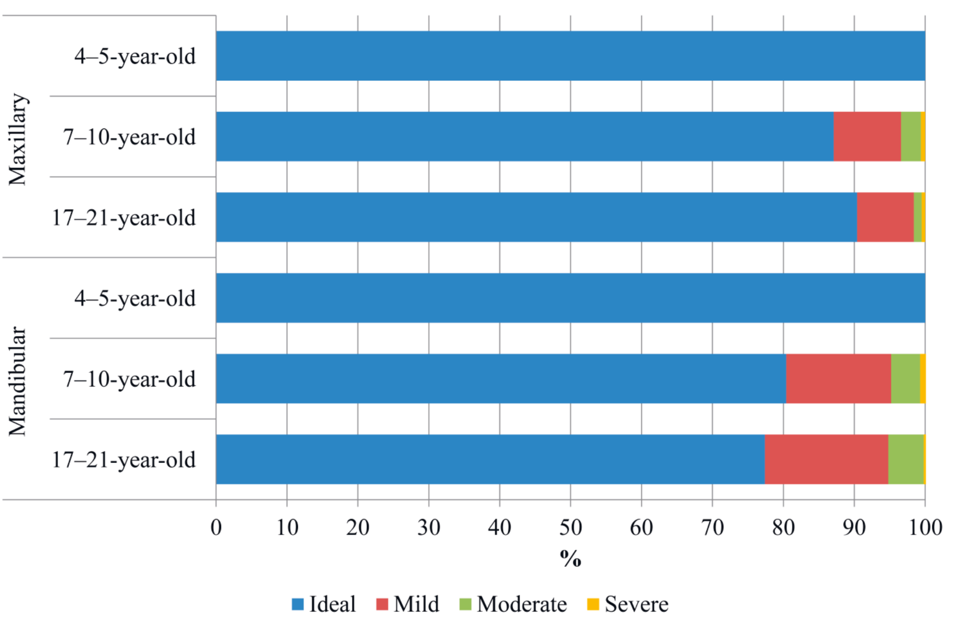

Figure 8. Crowding in Studies I, II, and III (n = 1172). 0–1 mm ideal; 2–3 mm mild; 4–6 mm moderate; 7–10 mm severe; >10 mm extreme.

6.4.2 Mandibular movements

Young adults had statistically significantly larger mandibular movements (MMO 54.3 mm, LMM 11.6 mm, PMM 8.6 mm) compared to children with mixed dentition (MMO 49.2 mm, LMM 11.05 mm, PMM 7.5 mm) and deciduous dentition (MMO 43.6 mm, LMM 9.5 mm, PMM 2.6 mm) (Appendix 9).

Gender differences in mandibular movement capacities were not found in Study I (deciduous dentition) and Study II (mixed dentition) only in protrusion. A gender difference was found in Study III (permanent dentition): young adult males had a statistically significantly larger maximum mouth opening and lateral and protrusive movements compared to females (Appendix 9).

Maximum mouth opening and lateral and protrusive movements were moderately/strongly correlated in Studies I, II, and III (Appendix 10).

Mandibular movement capacities were statistically significantly smaller in children (Studies I and II) with crossbite and open bite compared to children without corresponding occlusal traits. Mandibular movement capacities were larger in children (Studies I and II) with increased overjet and overbite compared to those without corresponding occlusal traits. PMM was larger in young adults with scissor bite and with increased overjet compared with those without the same occlusal trait (Appendices 11, 16, 20).

6.4.3 Orthodontic treatment need and complexity of treatment (ICON)

There were statistically significantly more children in need of orthodontic treatment in Study II than in Study III (87.5% vs 55.4%, $p < 0.001$) (Table 12). No gender difference was found ($p > 0.05$).

Table 12. Distribution of orthodontic treatment complexity in Studies II and III assessed with ICON.

Complexity	Study II		Study III		P
	n	%	n	%	
Mild (scores < 50)	152	38.8	116	29.7	**0.008**
Moderate (scores 51–63)	89	22.7	63	16.2	**0.021**
Difficult (scores 64–77)	55	14.0	29	7.4	**0.003**
Very difficult (scores > 77)	47	12.0	8	2.1	**0.001**
Total	343	87.5	216	55.4	**< 0.001**

6.4.4 Treatment demand, caregivers' and young adults' perceptions, and satisfaction with dental appearance

There was statistically significantly less satisfaction with the appearance of the teeth in Study II than in Study III and Study I (56.8% vs 75.8% vs 89.3% respectively, $p < 0.001$). The caregivers of Study II (7–10-year-old) children considered good function and easy teeth cleaning more important than young adults in Study III (17–21-year-old young adults). Orthodontic treatment was statistically significantly less important for aesthetic reasons in Study I than in Study II and Study III ($p < 0.05$) (Figure 9).

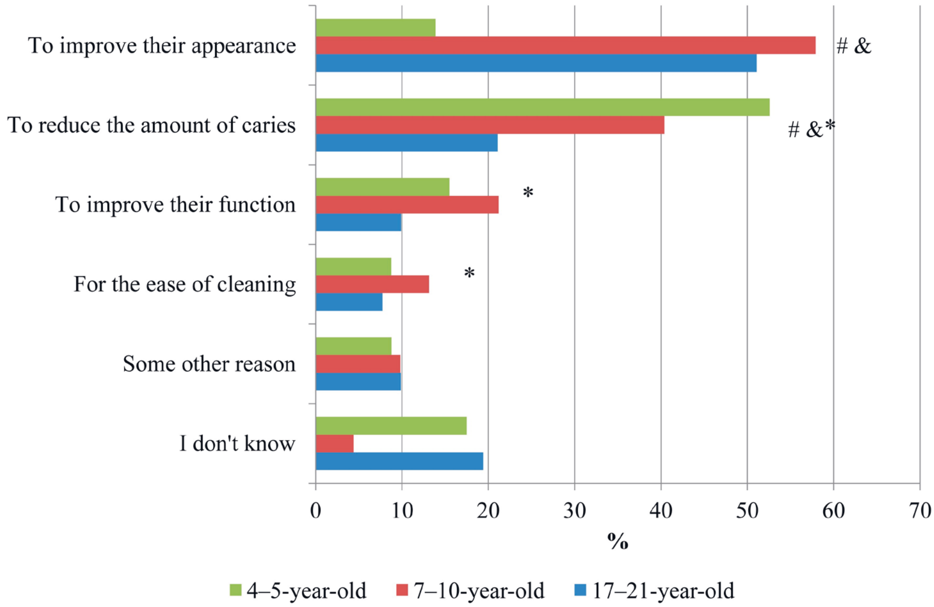

Figure 9. The reasons and expectations for orthodontic treatment listed by caregivers (Study I and Study II) and young adults (in Study III), and their expressed desire for orthodontic treatment in different age groups (n = 781). #A statistically significant difference existed between Study I and II ($p < 0.05$); &A statistically significant difference existed between Study I and III ($p < 0.05$); *A statistically significant difference existed between Study II and III ($p < 0.05$).

7 DISCUSSION

7.1 MORPHOLOGICAL VARIATION

7.1.1 Prevalence of occlusal traits

The prevalence of most occlusal traits in Estonian children was in line with those reported in the neighbouring countries of Finland, Sweden, and Germany, except for negative overbite and overjet, increased overjet, and a lack of crowding in the deciduous dentition (Keski-Nisula et al. 2003, Lux et al. 2009, Dimberg et al. 2013, 2015b). In the current study, the most prevalent occlusal trait was canine class I in all age groups, followed by midline diastema in the deciduous and mixed dentitions. In the mixed and permanent dentitions, a class I and end-to -end first molar relationship appeared in about half of the subjects. In most studies, sagittal findings have not been categorised into symmetrical and asymmetrical, even though, e.g. Sándor et al. (2007) report that asymmetry is a common finding in many craniofacial structures. In line with their finding, in the current study asymmetrical canine and molar relationships were the most common findings in all dental stages, although occlusal symmetry increased when age advanced.

7.1.2 Sagittal relationships

The sagittal relationship of the canines and molars is clinically important. However, there are studies where information on the sagittal relationships is not present for the canines and molars (Tschill et al. 1997, Ciuffolo et al. 2005), molars (Brunelle et al. 1996), or second deciduous molars (Dimberg et al. 2015b). In some studies, the sagittal relationship has been reported unilaterally despite recognised asymmetries (Kirzioglu et al. 2013). Grabowski et al. (2007) registered a class III relationship although the detailed observation was a class I on one side and a class III on the other side. Onyeaso and Sote (2002) registered a flush terminal plane when there was a flush terminal plane on one side and a distal terminal plane on the other side.

In the current study, a substantial number of combinations was found in right and left sagittal canine and molar relationships (Figures 2, 3, and 5): 50 combinations in the deciduous dentition; 79 combinations in the mixed dentition; and 75 combinations in the permanent dentition. Every seventh child in the deciduous dentition and every fifth in the mixed and permanent dentition had a particular combination of the canine and molar sagittal relationships.

This study indicates that the sagittal relationships of canines and molars in the permanent dentition are a result of changes in the number and patterns of combinations of sagittal relationships during the transition from deciduous to permanent dentition. Longitudinal studies would increase our knowledge and understanding of sagittal relationship development. This study was based on prevalence data, which limits the interpretation of the transition of occlusal traits. Despite the cross-sectional data, it can be seen from the patterns of different combinations that the canine relationship does not follow the direction of the molar relationship. In the literature, data provided in Figures 2, 3, and 5 do not exist. Thus, the comparison of these findings cannot be made with previous studies, even though the data on combinations have great clinical significance.

Sagittal relationships of the canines seem to be rather stable from the deciduous to mixed dentition. Therefore, in the mixed dentition, the relationship of the deciduous canines may be a more reliable reference than the first molars for the assessment of the sagittal relationships of the dentition. If the deciduous second molars are prematurely lost, the end-to-end relationship of the first molar and crowding are regular phenomena (Moorrees 1959, Perinetti et al. 2008).

Asymmetric canine and molar relationships were more frequent in Estonian children than in the other countries (Perinetti et al. 2008, Lux et al. 2009, Behbehani et al. 2012). Asymmetry is a common and clinically challenging finding in the craniofacial structures (Behbehani et al. 2012, Tervahauta et al. 2022).

7.1.3 Gender influence on the occlusal traits

Similarly to previous findings, no statistically significant differences existed in this study in any occlusal traits between boys and girls in the deciduous dentition

(Kirzioglu et al 2013, Dimberg et al. 2015b). In mixed dentitions, the girls had less crowding, smaller overjet, and more often a class I relationship in the deciduous canines and molars than the boys. Regarding overjet and overbite, our results confirm the previous gender differences (Ciuffolo et al. 2005, Grabowski et al. 2007), while Dimberg et al. (2015b) and Perinetti et al. (2008) did not report any gender differences in occlusal traits in the mixed dentition.

Gender differences in the occlusal traits have been reported in adults, with males having significantly more frequently increased overbite (Krooks et al. 2016), posterior crossbite (Jonsson et al. 2007), and open bite (Jonsson et al. 2007, Krooks et al. 2016) than females. In line with Study III, Laine and Hausen (1983) have reported that in Finland gender had no association on the prevalence of any occlusal trait in 17–51-year-olds.

7.1.4 Associations between occlusal traits

To the knowledge of the author, no studies exist on associations between different occlusal traits in deciduous or permanent dentitions, which precludes comparisons. Occlusal traits may individually change along with the development of the occlusion (Bishara et al. 1988, Ingelsson-Dahlström and Hagberg 1994, Dimberg et al. 2015b). Findings of a high rate of spontaneous corrections of the anterior open bite and posterior crossbite as well as the development of class II and III sagittal relationships have been reported by Dimberg et al. (2015b). In the present study, the association between gender and occlusal traits varied in all groups.

Significantly more children with an asymmetrical relationship in the deciduous canines or second molars had crossbite, like children with an end-to-end relationship and asymmetrical mesial terminal plane. A symmetrical or asymmetrical distal terminal plane was associated with increased overjet. In the permanent dentition, a statistically significantly higher proportion of young adults with a symmetrical or asymmetrical canine or first molar class II relationship had increased overjet and scissor bite, and a lower share had posterior crossbite. A higher proportion of those with increased overjet had an increased overbite and scissor bite.

Perinetti et al. (2008) reported that a class II molar sagittal relationship is positively correlated with increased overbite and overjet in 7–10-year-old children, and an asymmetrical class III sagittal relationship is strongly positively correlated with crossbite. In the current study, increased overjet and less crowding were associated with symmetrical or asymmetrical first molar/deciduous canine class II.

7.2 MANDIBULAR MOVEMENT CAPACITIES

7.2.1 MMO, LMM, and PMM

In the current study, the maximum mandibular movement capacity increased with age as found by Hirsch et al. (2006) and Müller et al. (2013). The mean for mandibular movement capacities in 7–10-year-old Estonian children was like the previous findings in 10–13-year-olds (Hirsch et al. 2006) and 8–10-year-olds (Steinmassl et al. 2017b). The mean for mandibular movement capacities in 17–21-year-olds was in line with that of 14–17-year-olds (Hirsh et al. 2006). However, in the present study, the means for maximum mouth opening and lateral movements in 4–5-year-olds were clearly larger than in a Brazilian sample of 4–6-year-olds (Cortese et al. 2007) as well as in 7–10-year-olds than in an Argentinian sample of 6–12-year-olds (Machado et al. 2009). A statistically significant difference was found between right and left lateral mandibular movement capacities in mixed dentition; the range of LMMr and LMMl was 15.0 and 17.0, respectively. This study showed that the LMMr and LMMl difference and asymmetry in occlusal traits occurred in a significant number of participants.

No gender differences were found in the deciduous dentition. The findings confirmed that young adult males have larger mandibular movements compared to females (Hirsch et al. 2006, Müller et al. 2013). In detail, the multivariable model by Hirsch et al. (2006) showed an increase of 0.4 mm in MMO per year. In the present study, boys had larger protrusive movements than girls already in the mixed dentition. Not all the reasons for the gender differences are known, but the overall size difference between individuals has an influence (Li et al. 2017). Whatever the cause, this study shows clearly that gender plays a role in mandibular movement capacities.

7.2.2 Correlations between mandibular movements and their associations with occlusal traits

In this study, in addition to the influence of age and gender on mandibular movement capacity, correlations between mandibular movements and associations between mandibular movements and occlusal traits were analysed. In all age groups, right and left lateral movements were strongly correlated, while the correlations with other movements increased from weak to moderate with increasing age. To the best of the author's knowledge, the associations between occlusal traits and mandibular mobility have not been previously studied.

The correlations found in this study between MMO, LMMr, LMMl, and PMM are clinically valuable. Anatomical relationships, including the anatomical form of the mandibular condyle and glenoid fossa, are related to the mandibular movement capacity and depend on the relationship between occlusion and the condylar position (Karlo et al. 2010). The masticatory system can adapt continuously to changes in occlusal traits (Roberts and Goodacre, 2020). Niwa and Takahashi (2023) have described the relationship between the movement and activity of the masticatory muscles. Zonnenberg et al. (2021) have shown that every individual has a unique occlusion and TMJ relationship.

Increased overbite and overjet were associated with larger mandibular movement capacities. In the deciduous dentition, MMO was larger in children with increased overbite and overjet, in the mixed dentition MMO was larger in children with increased overbite, and in permanent dentition PMM was larger in young adults with increased overbite and overjet compared to those without the corresponding occlusal traits.

Crossbite and open bite were associated with smaller mandibular movement capacities – in deciduous and mixed dentitions MMO was smaller in children with crossbite and open bite, and in deciduous dentitions LMMr and LMMl were smaller in children with crossbite compared to those without the corresponding occlusal traits.

7.3 ORTHODONTIC TREATMENT NEED AND DEMAND

7.3.1 Patient expectations

It is well known that high parental education and economic status affect the perception of orthodontic treatment need (Badran and Al-Khateeb 2013, Tuncer et al. 2015, Chambers and Zitterkopf 2019). The socio-economic background of Finnish adults does not seem to affect seeking aesthetic treatment (Campos et al. 2022a). In this study, socio-economic indicators were not used. Social desirability bias cannot be excluded from having influenced the present findings (Swedish Council on Health Technology Assessment).

As shown in several studies, caregivers expect improvements in the child's self-image, oral function, and social life (Tung and Kiyak 1998, Benson et al. 2015). They are often more interested in orthodontic treatment than the children themselves (Birkeland et al. 1996, Chew and Aw 2002, Daniels et al. 2009, Dias and Gleiser 2010).

In the literature, the desire to improve facial and dental aesthetics is the most mentioned reason for seeking orthodontic treatment (Trulsson et al. 2002, Wedrychowska-Szulc and Syryńska 2010, Feldens et al. 2015, van Wezel et al. 2015,). According to Imani et al. (2018), the hope for a better future tremendously affects the decision-making process when it comes to receiving orthodontic treatment. Positive effects of treatment are expected on social relations, self-image, and dental health and function (Trulsson et al. 2002, Wedrychowska-Szulc and Syryńska 2010, Prabakaran et al. 2012, Imani et al. 2018). In the current study, improvements in appearance and function as well as the facilitation of tooth cleaning and reduction of caries were highlighted as the main expectations of the treatment.

7.3.2 Objective need and subjective demand for orthodontic treatment

The ICON-determined treatment need in the mixed and permanent dentitions were 64.0% and 36.0%, respectively. Of these, treatments were estimated to be difficult or very difficult in 26.0% and 9.5%, respectively. No gender differences in treatment need were found.

Orthodontic treatment depends on the dental developmental stage and is a highly individual experience. Therefore, it was of interest to focus on the professionally determined treatment need and patient-determined treatment demand at different developmental dental stages. In this study, caregivers' and young adults' desire for orthodontic treatment were in line with the professional assessment of treatment need. However, results of earlier studies indicate that professional and children's or caregivers' perceptions do not always coincide. The self-perceived treatment need can be higher (Stenvik et al. 1997, Christopherson et al. 2009, Dias and Gleiser 2010,), lower (Tang and So 1995, Soh and Sandham 2004), or – like in this study – coincide with the professionally assessed treatment need (Birkeland et al. 1996, Chew and Aw 2002, Marques et al. 2005). The percentage of treatment need in mixed dentition corresponded with the findings of Birkeland et al. (1996), and likewise caregivers' opinions regarding treatment need did not differ for girls and boys.

According to Birkeland et al. (1996) children with great and very great treatment need and low self-esteem often do not express orthodontic concern. Parental concern is a powerful factor in the motivation for treatment (Prado et al. 2022), and mothers in particular play an important role in deciding whether to commence orthodontic treatment or not (Imani et al. 2018). In this study, most caregivers (57–89%) were satisfied with their child's dental appearance, as were most young adults (76%) with their own dental appearance. This indicates that caregivers seem to pay attention to the professionally important occlusal traits in their child's dentition. In deciduous dentition, concerned caregivers focused on open bite, deep bite scissor bite, and a class III relationship in the canines. In mixed dentitions, they focused on deciduous canine class III, crossbite, and crowding. However, they mostly mentioned a reduction in the amount of caries as the main reason for orthodontic treatment.

7.3.3 Associations between orthodontic treatment need and demand

Some findings in this study contradict the findings in the literature. The subjectively assessed treatment need in Brazilian 9–12-year-old children (22.6%) was lower than the objective treatment need (45.5%) (Dias and Gleiser 2010), and in another study 8–11-year-old American children's parent-determined treatment need was considerably greater than the objective treatment need (46.9% vs 17.1%) (Christopherson et al. 2009).

In contrast to Estonian young adults with a 36% treatment need, the subjective need among Finnish 16–17-year-olds was higher (48%) (Tuominen et al. 1994), and among 15–16-year-olds lower (29%) (Pietilä and Pietilä 1996), indicating variability in populations within one country. The young adults' main expectation regarding orthodontic treatment was an improvement in dental appearance. This finding is supported by other studies (Pietilä and Pietilä 1996, Cai et al. 2018, Deng et al. 2018). Motivation and attitudes towards orthodontic appliances, cost of treatment, professional recommendations, and socioeconomic level vary between countries. The demand for orthodontic treatment reflects all these differences.

7.4 METHODOLOGICAL ASPECTS

The difficulty of taking exact measurements in young children has been pointed out previously (Cortese et al. 2007). Present experience confirmed that a lot of patience, diligence, and time are needed when examining young children.

The widely used clinical method of measuring mandibular movement capacities with a ruler was reliable (inter- and intra-examiner $r \geq 0.98$), and it is simple, cheap, and quick (Hirsch et al. 2006, Cortese et al. 2007, Okeson 2008, Karlo et al. 2010, Müller et al. 2013, Steinmassl et al. 2017b).

Questionnaires are widely used to gather data on subjects' opinions regarding, e.g. the psychological impact of dental appearance and subjective treatment need (Bevans et al. 2020). In this study, the questionnaire developed by Pietilä and Pietilä (1996) was used because it is specific, short, and relevant to all age groups.

The importance to asking young adults' subjective opinions on their oral health and aesthetics has been highlighted, because they are often concerned about dental aesthetics (Pietilä and Pietilä 1996, Bevans et al. 2020, Campos et al. 2022a, 2022b).

Tung and Kiyak (1998) have reported that by the age of eight years, children are capable of assessing aesthetics similarly to adults. On the other hand, around the age of six years, children begin to compare their physical features with those of other children, or against societal, ethnic, or cultural norms (Shaw 1981, Varatharaju et al. 2021). In contrast, Birkeland et al. (1996) suggested that until the age of eleven years, children have a restricted ability to evaluate their own appearance consistently. In this study, the level of knowledge on oral health was considered low at ages of 4–10 years, and therefore the questionnaires were targeted at the caregivers.

ICON (Daniels and Richmond 2000) was used in this study because it can be used on plaster casts, and the assessment does not take a long time, which is an important issue in large studies. In ICON, maxillary anterior crowding is considered the principal risk factor for aesthetic impact, and it causes dissatisfaction with the appearance and a desire for orthodontic treatment (Dias and Gleiser 2010). This study showed that the ICON assessments can be used in mixed dentition, even though it was originally developed for the assessment of permanent dentition.

7.5 PROS AND CONS

One strength of this study is that a single examiner performed all the clinical examinations with a high reproducibility. In addition to the examination, the plaster casts were taken and diversely examined. The sample size was relatively large and ethnically and economically homogeneous.

The study focused on children and young adults in the deciduous, mixed, and permanent dentition, and the age groups were selected to strictly represent those dental developmental stages. In addition to conventional measures, the statistical analyses also included correlations and associations between the examined variables. The results provided novel data on associations between mandibular movement capacities and occlusal traits.

There were some weaknesses, too. In measurements of lateral mandibular movements, the extent of mouth opening was not observed, nor was the participants' physical size related to the range of movements. The participants' medical records were not available, hence it is possible that the sample included some individuals with diseases affecting mandibular movements. Unfortunately, protrusion could not be measured in some of the youngest participants in Study I.

The questionnaires to the caregivers were sent via their child. Some children first returned the questionnaires after the clinical examination, which may have influenced the responses.

7.6 FUTURE PERSPECTIVES

Combinations of sagittal canine and molar relationships in different dental stages is worth closer investigation. Future studies should focus on aspects raised in this study, and more attention should be paid to the various combinations of sagittal relationships.

A great need exists to find a consensus on the registration methods of mandibular movement capacity and criteria to register occlusal traits in epidemiological studies. Longitudinal studies covering an extended time span would provide more detailed information about the natural variation in mandibular movement capacities over time and in the relationships of static and dynamic structures determining the impact of this relationship within the maxillofacial system.

Furthermore, it would be interesting to know whether this would add to the common knowledge to describe the natural history and prognosis, to homogenise the prevalence of occlusal traits and treatment need and severity, and to evaluate the possible effects of (existing and new) preventive and therapeutic interventions to develop models of dental or orthodontic delivery of care, facilities, and training of current and future orthodontists.

Future studies should focus on how to advise general practitioners/dentists to refer children at the proper developmental stage to orthodontic treatment.

8 CONCLUSIONS

PREVALENCE OF OCCLUSAL TRAITS

The most prevalent occlusal traits were as follows:

In Study I: a symmetrical sagittal relationship in the deciduous canines and molars, a class I sagittal relationship in the deciduous canines, a mesial terminal plane in the deciduous second molars, and midline diastema.

In Study II: a class I canine sagittal relationship, midline diastema, a class I molar sagittal relationship, and increased overbite. More than half of the children had an asymmetrical canine and molar relationship.

In Study III: a class I sagittal relationship in the canines and molars, crowding, increased overbite, an end-to-end sagittal relationship in the canines, and increased overjet. More than half of the young adults had an asymmetrical canine and molar sagittal relationship.

There were statistically significant differences between age groups in asymmetrical sagittal relationship, crowding, midline diastema, and posterior and anterior crossbite.

Although asymmetrical canine and molar relationships are the most common findings in all dental stages, symmetry increased when age advanced.

In deciduous and permanent dentitions, no gender differences exist in any of the occlusal traits. In mixed dentitions, girls have more crowding, a smaller overjet, and more often class I relationships in deciduous canines and molars compared to boys.

MANDIBULAR MOVEMENT CAPACITIES

Age and gender influence mandibular movements. The mandibular movement capacity increased with age. In the deciduous dentition, there were no gender differences. In the permanent dentition, all movements were larger in males than females.

ASSOCIATIONS BETWEEN MANDIBULAR MOVEMENTS AND OCCLUSAL TRAITS

Mandibular movements were smaller in children with crossbite and open bite, and they were larger in children with increased overjet and overbite compared to those without the same occlusal traits.

ORTHODONTIC TREATMENT NEED AND DEMAND

Only 7.0% of 4–5-year-olds had occlusal traits expecting a favourable occlusal transition. Caregivers seem to be able to observe occlusal traits and functions deviating from the so-called "normal". The majority (89.3%) of caregivers were satisfied with the child's teeth.

Of the 7–10-year-olds, 64.3% needed orthodontic treatment. A statistically significant association was found between caregivers' desire to get the child's teeth straightened and professionally assessed treatment need. Caregivers' opinion regarding orthodontic treatment need did not differ according to the child's gender. One half of the caregivers were satisfied with the appearance of the child's teeth.

Of the 17–21-year-olds, 36.0% needed orthodontic treatment. A statistically significant association was found between young adults' desire to get their teeth straightened and the professional treatment need. The subjective treatment need did not differ between genders. Three quarters of young adults were satisfied with their own dental appearance.

In mixed and permanent dentitions, orthodontic treatment need in Estonian children and young adults was in line with that of neighbouring countries.

Of the original hypotheses, only one has to be rejected. The occlusal traits perceived by caregivers were similar to those assessed by an orthodontist.

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11 APPENDICES

Appendix 1. Registration criteria of occlusal traits in the clinical examination and from the plaster casts.

Sagittal plane

The sagittal relationship of the first permanent molars was registered between perpendicular projections on the occlusal plane from the tip of the triangular ridge of the mesiobuccal cusp of the maxillary first permanent molar and the buccal groove of the mandibular first permanent molar.

Molar class I: the triangular ridge articulated in the buccal groove of the mandibular first permanent molar.

Molar class II: the triangular ridge articulated anterior to the mesial groove of the mandibular first permanent molar.

Molar class III: the triangular ridge articulated posterior to the mesial groove of the mandibular first permanent molar.

End to end: the triangular ridge of the mesiobuccal cusp of the maxillary first permanent molar articulated to the triangular ridge of the mesiobuccal cusp of the mandibular first permanent molar.

Molar class II and class III were registered with an accuracy of $\geq 1/2$ cups wide. In cases of obvious tooth migration, no attempt was made to attempt the original intercuspation. Registration was not done when the first molar was missing.

The sagittal relationship of the canines was measured between perpendicular projections on the occlusal plane from the tip of the maxillary canine and the contact point of the mandibular canine and the first deciduous molar/the first premolar.

Canine class I: the tip of the maxillary canine occluded to the distal surface of the mandibular canine.

Canine end to end: the tip of the maxillary canine articulated to the tip of the mandibular canines. A deviation of 1 mm or more to the mesial or distal was classified as canine class II or class I, respectively.

Canine class III: the tip of the maxillary deciduous canine occluded more than 1 mm posterior to the distal surface of the mandibular canine.

In the case of a missing canine, the registration was not recorded. No attempt was made to compensate for the drift of teeth due to premature extraction or any other reasons.

The sagittal relationship of the second deciduous molars was registered between perpendicular projections on the occlusal plane from the distal surface of the mandibular second deciduous molar and the distal surface of the maxillary second deciduous molar.

Distal terminal plane: the distal surface of the mandibular second deciduous molar is distal to the corresponding surface in the maxillary second deciduous molar.

Mesial terminal plane: the distal surface of the mandibular second deciduous molar is mesial to the corresponding surface in the maxillary second deciduous molar.

Flush terminal plane: the distal surface of the mandibular and maxillary second deciduous molar end in the same vertical plane.

A negative overjet was measured in 0.5 mm intervals as the horizontal distance, parallel to the occlusal plane from the most labial surface of the upper central incisor to the most labial point of the incisal edge of the corresponding lower central incisors.

The anterior crossbite was registered in the incisor area when the incisal edge of the maxillary tooth occluded lingually to the mandibular antagonists (at least one pair of teeth).

Vertical plane

The overbite (positive) was measured in 0.5 mm intervals as the distance between the projection of the edge of the most overlapped central incisor on the labial surface of the lower incisors (in centric occlusion) and the incisal edge of the lower incisor.

A negative overbite was recorded when there existed a vertical space between the upper and lower incisal edges in the centric occlusion. The negative overbite was measured in 0.5 mm intervals from the incisal edge of the lower incisors to the incisal edge of the upper corresponding incisors.

Sagittal and vertical plane

Open bite was registered when there existed no contacts between the upper and lower incisal edges in the centric occlusion.

Transversal plane

A posterior crossbite was registered in the canine, premolar, and molar area when the buccal cusp of the maxillary tooth occluded lingual to the buccal cusp of the mandibular antagonists (at least one pair of teeth). Teeth in an end-to-end position were registered as a crossbite.

A scissor bite was recorded in the premolar and molar area when the lingual cusps of maxillary teeth occluded buccally to the buccal surfaces of the corresponding mandibular teeth.

Crowding

Crowding of the teeth was estimated as the total space deficiency (in millimeters) of the anterior teeth (incisors only). The amount of crowding was recorded in the maxillary and mandibular arch as the difference between the total mesio-distal tooth diameter and the arch circumference. The possible influence of growth in arch width was not estimated.

Midline diastema

Midline diastema between the central incisors in the upper and lower arch was measured in 0.5 mm intervals between the mesial margin of the right and left incisors on the mid-height of the tooth crown.

Appendix 2. ICON.

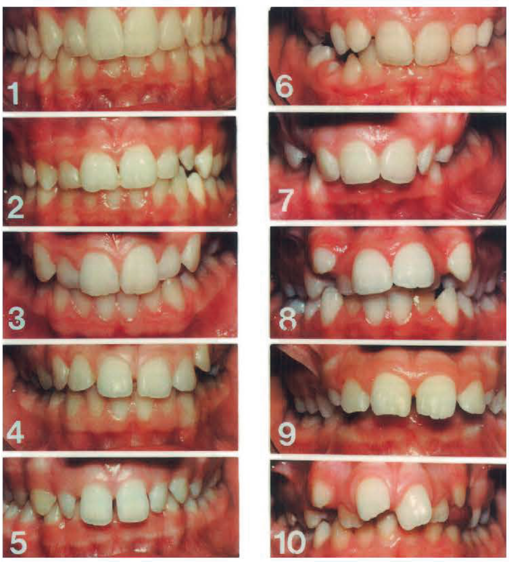
A ICON SCORING PROTOCOL

Score	0	1	2	3	4	5	Weighting
1 Aesthetic component	Score 1 to 10						7
2 Upper arch crowding	< 2mm	2.1 to 5mm	5.1 to 9mm	9.1 to 13mm	13.1 to 17mm	> 17mm	5
Upper spacing	< 2mm	2.1to 5mm	5.1 to 9mm	> 9mm		Impacted teeth	5
3 Crossbite	No cross-bite	Cross-bite present					5
4 Incisor open bite	Com-plete bite	< 1mm	1.1 to 2mm	2.1 to 4mm	> 4mm		4
Incisor overbite	1/3 lower incisor cove-rage	1/3 to 2/3 cove-rage	2/3 up to fully cove-red	fully cove-red			4
5 Buccal segment antero-posterior	Cusp to embra-sure only. Class I, II or III	Any cusp rela-tion up to but not incl. cusp to cusp	Cusp to cusp				3

B ICON SCORING

- Measure all 5 traits according to the protocol above to obtain a set of scores
- Multiply the scores by their respective weights
- The sum of the weighted scores is the ICON score for the case
- Pre-treatment scores give the treatment need and complexity grades
- End of treatment scores gives the acceptability
- Pre-treatment – 4 x post treatment scores give the degree of improvement

1 Aesthetic assessment



2 Upper arch crowding / spacing

- The difference between the sum if the mesio-distal tooth diameters and the available arch circumference in the upper arch reduced to a 5-point score
- Impacted teeth in either arch immediately score 5
    - Ectopic or impacted against an adjacent tooth (excluding third molars but including supernumerary teeth)
    - Possess less than or equal to 4mm of space between the adjacent permanent teeth. Use average canine and premolar widths to estimate the potential crowding in the mixed dentition, namely, 7mm for premolars, lower canine, and 8mm for upper canine
- Spacing in one part of the arch will cancel out crowding elsewhere
- Retained deciduous teeth (without permanent successor) and erupted supernumerary teeth score as space (unless they are to be retained to obviate the need for prosthesis)
- Lost teeth due to trauma or extraction should be counted as space

3 Crossbite

- Anterior and posterior transverse discrepancies of cusp to cusp or greater in intercuspal position

4 Incisor open bite / overbite

- Open bite (excluding developmental conditions) is measured to the incisal edges
- Deep bite is measured to deepest part of overbite
- If both traits are present only the highest scoring raw score is counted

5 Buccal segment antero-posterior relationship

- Quality of buccal segment interdigitation is measured (not Angles classification)
- Both sides are scored then added together

C INTERPRETATION OF ICON SCORES

Need and acceptability	**Threshold**
Pre-treatment need	> 43 treatment need
End treatment acceptability	< 31 acceptable
Complexity Grade (pre-treatment)	**Score range**
Easy	< 29
Mild	29 to 50
Moderate	51 to 63
Difficult	64 to 77
Very difficult	> 77
Improvement Grade (Pre-treat score - 4 x post-treat score)	**Score range**
Greatly improved	> -1
Substantially improved	-25 to -1
Moderately improved	-53 to -26
Minimally improved	-85 to -54
Not improved or worse	< -85

Appendix 3. The questionnaire Study I, Study II.

1. How satisfied are you with the dental health of your child?

   Very satisfied / Satisfied / I don't care / Somewhat dissatisfied / Very unsatisfied / I don't know

2. How satisfied are you with the alignment of your child's teeth?

   Very satisfied / Satisfied / Somewhat dissatisfied / Very unsatisfied / I don't know

3. Do you think that your child needs orthodontic treatment?

   Definitely not / No, I don't think so / Yes, I think so / Yes, definitely

4. For what reason would you like to align your child's teeth?

   To improve their appearance / To improve their function / For ease of cleaning / To reduce caries / Other reasons / I don't know

5. Has your child ever worn an orthodontic appliance or is your child wearing one now?

   Yes / No / I don't know

Appendix 4. The questionnaire Study III.

1. How satisfied are you with your dental health?

   Very satisfied / Satisfied / I don't care / Somewhat dissatisfied / Very unsatisfied / I don't know

2. How satisfied are you with the alignment of your teeth?

   Very satisfied / Satisfied / Somewhat dissatisfied / Very unsatisfied / I don't know

3. Do you think that you need orthodontic treatment?

   Definitely not / No, I don't think so / Yes, I think so / Yes, definitely

4. For what reason would you like to align your teeth?

   To improve their appearance / To improve their function / For ease of cleaning / To reduce caries / Other reasons / I don't know

5. Have you ever worn an orthodontic appliance or are you wearing one now?

   Yes / No / I don't know

Appendix 5. Occurrence of occlusal traits by gender in 4–5-year-old children (n = 390).

	Girls (%)	Boys (%)	OR	95% CI	Sig
Canine class I	71.1	68.5	1.13	0.73–1.74	0.583
Midline diastema	67.4	68.0	0.97	0.64–1.49	0.894
Mesial terminal plane	45.3	50.5	0.81	0.54–1.21	0.301
Flush terminal plane	46.3	39.5	1.32	0.88–1.98	0.174
Canine end to end	44.7	39.5	1.24	0.83–1.86	0.295
Overbite ≥ 3.5 mm	41.1	36.5	1.21	0.81–1.82	0.356
Distal terminal plane	35.3	32.0	1.16	0.76–1.76	0.495
Anterior open bite	15.3	21.0	0.68	0.40–1.14	0.144
Crossbite	16.8	18.5	0.89	0.53–1.50	0.668
Overjet ≥ 3.5 mm	12.1	19.0	0.59	0.34–1.03	0.063
Canine class II	6.3	5.0	1.28	0.54–3.04	0.574
Canine class III	4.2	3.5	1.21	0.43–3.41	0.716
Scissor bite	4.7	2.0	2.41	0.73–7.97	0.149
Overbite < 0 mm	2.6	3.5	1.34	0.42–4.30	0.621
Overjet < 0 mm	3.2	1.5	0.47	0.12–1.90	0.287
Crowding	0.5	0.0	-	-	-

Appendix 6. Distribution of the sagittal relationship of the deciduous canines in 4–5-year-old children (n = 390).

		Left side				
		No canine (n = 1)	Class I (n = 236)	End to end (n = 129)	Class II (n = 10)	Class III (n = 14)
Right side	No canine (n = 1)			1		
	Class I (n = 240)		204	34		2
	End to end (n = 121)	1	28	86	2	4
	Class II (n = 20)		3	8	8	1
	Class III (n = 8)		1			7

Appendix 7. Distribution of the sagittal relationship of the deciduous second molars in 4–5-year-old children (n = 390).

		Left side			
		No molar (n = 1)	Distal terminal plane (n = 100)	Flush terminal plane (n = 135)	Mesial terminal plane (n = 154)
Right side	No molar (n = 1)			1	
	Distal terminal plane (n = 108)	1	77	20	10
	Flush terminal plane (n = 123)		13	91	19
	Mesial terminal plane (n = 158)		10	23	125

Appendix 8. Distribution of crossbite and scissor bite by age group (n = 1172).

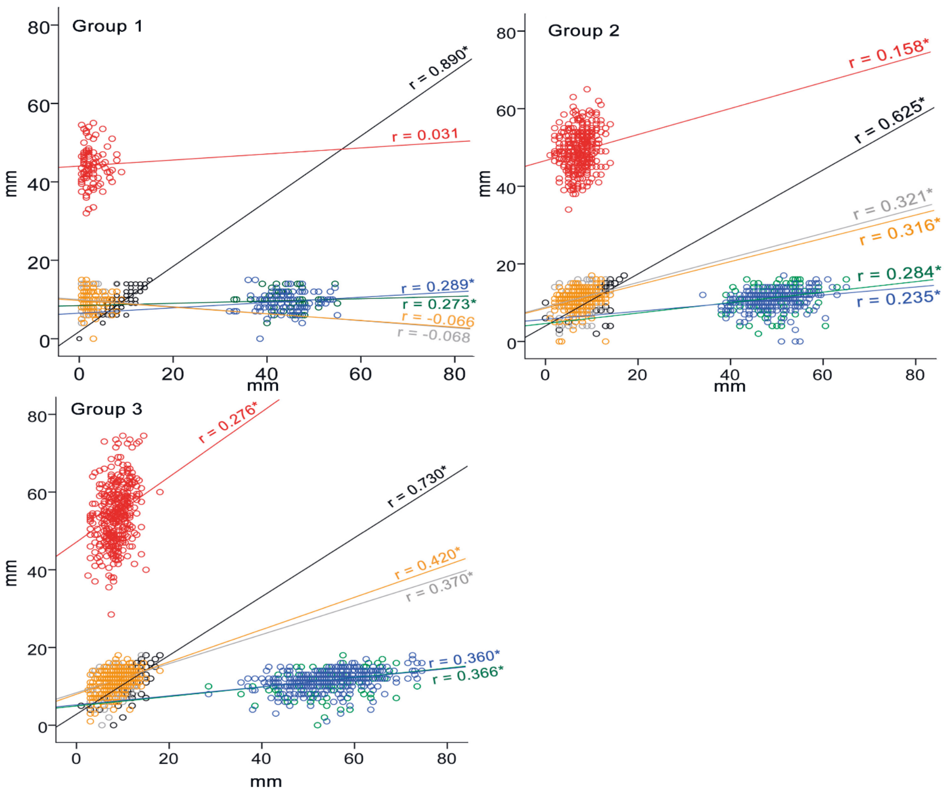
	4–5-year-old (n = 390)		7–10-year-old (n = 392)		17–21-year-old (n = 390)	
	n	%	n	%	n	%
Posterior crossbite	68	17.4	47	12.0	107	27.4
Crossbite right	26	6.7	27	6.9	35	9.0
Crossbite left	17	4.4	12	3.1	40	10.3
Bilateral crossbite	25	6.4	8	2.0	32	8.2
Anterior crossbite	33	8.5	9	2.3	24	6.2
Bilateral and anterior crossbite	16	4.1	2	0.5	9	2.3
End to end (OJ = 0 mm)	6	1.5	7	1.8	9	2.3
Scissor bite	13	3.3	6	1.5	10	2.6

Appendix 9. Mandibular movement capacities in deciduous (Group 1, n = 372), mixed (Group 2, n = 390), and permanent dentition (Group 3, n = 390), and gender differences. The mean ± standard deviation and odds ratios (OR) with 95% confidence interval, Ref: females.

		Girls	Boys	OR (95% CI)
4–5-year-old	MMO	43.7 ± 4.6	43.6 ± 4.6	1.00 (0.96–1.04)
	LMM right	9.5 ± 2.7	9.5 ± 2.6	1.00 (0.92–1.08)
	LMM left	9.4 ± 2.7	9.4 ± 2.6	1.00 (0.93–1.08)
	PMM	2.7 ± 1.8	2.6 ± 2.0	0.97 (0.79–1.18)
7–10-year-old	MMO	49.3 ± 4.7	49.0 ± 5.2	0.99 (0.95–1.03)
	LMM right	11.2 ± 2.3	11.3 ± 2.4	1.03 (0.94–1.12)
	LMM left	10.8 ± 2.0	10.8 ± 2.3	1.01 (0.92–1.10)
	PMM	7.1 ± 2.3	7.9 ± 2.2	**1.15 (1.06–1.26)** #
17–21-year-old	MMO	52.1 ± 6.5	57.3 ± 7.8	**1.11 (1.07–1.15)** #
	LMM right	11.3 ± 2.3	11.9 ± 2.7	**1.11 (1.02–1.21)** #
	LMM left	11.2 ± 2.4	12.1 ± 2.4	**1.19 (1.08–1.31)** #
	PMM	8.2 ± 2.3	9.0 ± 2.7	**1.15 (1.05–1.25)** #

#Statistically significant difference between gender ($p < 0.05$).

Appendix 10. Correlations of maximum mouth opening (MMO), lateral (LMMr and LMMl) and protrusive (PMM) movements in deciduous (Group 1, n = 372), mixed (Group 2, n = 392), and permanent dentition (Group 3, n = 390). *Statistically significant correlations between mandibular movements ($p < 0.05$). Black–LMMr vs LMMl, red–MMO vs PMM, blue–MMO vs LMMl, green–MMO vs LMMr, grey–PMM vs LMMr, yellow–PMM vs LMMl.



Appendix 11. Occlusal traits and the mean ± standard deviation for mandibular movements (MMO, LMMr, LMMl, PMM) in the deciduous dentition (n = 372).

	MMO		LMMr		LMMl		PMM	
	With OT	Without OT	With OT	Without OT	With OT	Without OT	With OT	Without OT
Mesial terminal plane	44.2 ± 4.4 (n=131)	43.4 ± 4.7 (n=259)	**10.1 ± 2.0 (n=130)**	**9.2 ± 2.8* (n=259)**	9.7 ± 2.1 (n=131)	9.3 ± 9.7 (n=259)	3.1 ± 2.2 (n=29)	2.5 ± 1.8 (n=77)
Flush terminal plane	44.0 ± 4.3 (n=167)	43.4 ± 4.8 (n=223)	**9.1 ± 2.5 (n=167)**	**9.7 ± 2.7* (n=222)**	9.3 ± 2.4 (n=167)	9.5 ± 2.8 (n=223)	2.3 ± 1.6 (n=49)	2.9 ± 2.2 (n=57)
Distal terminal plane	**43.1 ± 4.8 (n=187)**	**44.1 ± 4.4* (n=203)**	9.4 ± 3.0 (n=187)	9.5 ± 2.3 (n=202)	9.3 ± 3.0 (n=187)	9.5 ± 2.2 (n=203)	2.4 ± 1.8 (n=55)	2.9 ± 2.0 (n=51)
Canine Cl I	43.6 ± 4.3 (n=272)	43.9 ± 5.3 (n=118)	9.5 ± 2.6 (n=271)	9.5 ± 2.7 (n=118)	9.5 ± 2.6 (n=272)	9.3 ± 2.8 (n=118)	2.4 ± 1.8 (n=79)	3.3 ± 2.3 (n=27)
Canine Cl II	44.2 ± 3.9 (n=22)	43.6 ± 4.6 (n=368)	10.1 ±2.3 (n=22)	9.4 ± 2.6 (n=367)	9.6 ± 2.2 (n=22)	9.4 ± 2.7 (n=368)	-	2.6 ± 1.9 (n=101)
Canine Cl III	**38.6 ± 7.4 (n=15)**	**43.9 ± 4.4* (n=375)**	8.9 ± 4.0 (n=15)	9.5 ± 2.6 (n=374)	8.5 ± 4.1 (n=15)	9.5 ± 2.6 (n=374)	-	2.7 ± 1.9 (n=103)
Canine end to end	**44.4 ± 4.3 (n=164)**	**43.1 ± 4.8* (n=226)**	9.6 ± 2.3 (n=163)	9.4 ± 2.8 (n=226)	9.5 ± 2.3 (n=164)	9.4 ± 2.9 (n=226)	2.7 ± 2.0 (n=38)	2.6 ± 1.9 (n=68)
OJ ≥ 3.5 mm	**45.3 ± 4.2 (n=61)**	**43.3 ± 4.6* (n=329)**	9.5 ± 2.7 (n=61)	9.5 ± 2.6 (n=328)	9.2 ± 2.7 (n=61)	9.4 ± 2.6 (n=329)	**5.2 ± 1.7 (n=61)**	**2.2 ± 1.6* (n=90)**
Negative OJ (< 0)	**36.8 ± 7.8 (n=15)**	**43.9 ± 4.2* (n=375)**	**7.3 ± 5.5 (n=15)**	**9.6 ± 2.4* (n=374)**	**7.1 ± 5.3 (n=15)**	**9.5 ± 2.5* (n=375)**	-	2.6 ± 1.9 (n=105)
OB ≥ 3.5 mm	**45.4 ± 4.1 (n=107)**	**43.0 ± 4.6* (n=283)**	**10.2 ± 2.2 (n=107)**	**9.2 ± 2.7* (n=282)**	**10.0 ± 2.1 (n=107)**	**9.2 ± 2.8* (n=283)**	3.0 ± 1.9 (n=27)	2.5 ± 1.9 (n=79)
Negative OB (< 0)	**38.0 ± 6.5 (n=12)**	**43.8 ± 4.4* (n=378)**	9.6 ± 3.4 (n=12)	9.5 ± 2.6 (n=377)	9.4 ± 2.6 (n=12)	9.4 ± 3.3 (n=378)	-	2.7 ± 1.9 (n=103)
Crossbite	**42.1 ± 5.2 (n=68)**	**44.0 ± 4.4* (n=322)**	**8.8 ± 3.5 (n=68)**	**9.6 ± 2.4* (n=322)**	**8.5 ± 3.6 (n=68)**	**9.6 ± 2.4* (n=322)**	**1.6 ± 1.5 (n=16)**	**2.8 ± 1.9* (n=90)**
Scissor bite	-	43.7 ± 4.7 (n=375)	-	9.5 ± 2.6 (n=374)	-	9.4 ± 2.6 (n=375)	-	2.6 ± 1.9 (n=104)

*Statistically significant difference between children with certain occlusal traits compared with those without the corresponding occlusal trait ($p < 0.05$). - = fewer than five cases.

Appendix 12. Occurrence of occlusal traits by gender in 7–10-year-old children (n = 392).

	Girls (%)	Boys (%)	OR	95%CI	Sig
Canine class I	75.3	72.2	1.17	0.75–1.84	0.488
Midline diastema	56.6	62.9	0.77	0.51–1.15	0.202
Molar class I	54.5	60.3	0.79	0.53–1.18	0.249
Molar end to end	58.1	50.0	1.39	0.93–2.06	0.109
Overbite ≥ 3.5 mm	49.0	54.6	0.80	0.54–1.19	0.263
Canine end to end	**34.3**	**49.0**	**0.55**	**0.36–0.82**	**0.003**
Overjet ≥ 3.5 mm	**31.8**	**43.3**	**0.61**	**0.41–0.92**	**0.019**
Crowding	**39.4**	**28.9**	**1.60**	**1.05–2.44**	**0.028**
Molar class II	**16.2**	**27.8**	**0.50**	**0.21–0.82**	**0.006**
Anterior open bite	20.2	22.7	0.86	0.53–1.40	0.550
Crossbite	10.1	13.9	0.70	0.38–1.29	0.247
Canine class II	2.5	4.6	0.53	0.18–1.62	0.267
Canine class III	2.0	2.6	0.78	0.21–2.95	0.713
Molar class III	2.0	1.0	1.98	0.36–10.90	0.434
Scissor bite	1.0	2.1	0.49	0.09–2.68	0.406
Overbite < 0 mm	1.0	2.1	2.06	0.37–11.40	0.406
Overjet < 0 mm	0.5	1.5	3.09	0.32–30.00	0.330

Appendix 13. Distribution of the sagittal relationship of the canines in 7–10-year-old children (n = 392).

		Left side				
		No canine (n = 35)	Class I (n = 240)	End to end (n = 101)	Class II (n = 9)	Class III (n = 7)
Right side	No canine (n = 25)	13	7	5		
	Class I (n = 230)	15	181	29		5
	End to end (n = 124)	7	50	62	5	
	Class II (n = 9)		1	4	4	
	Class III (n = 4)		1	1	0	2

Appendix 14. Distribution of the sagittal relationship of the first molars in 7–10 - year-old children (n = 392).

		Left side				
		No molar (n = 2)	Class I (n = 192)	End to end (n =148)	Class II (n = 46)	Class III (n = 4)
Right side	No molar (n = 3)	2		1		
	Class I (n = 155)		122	22	9	2
	End to end (n = 161)		56	97	8	
	Class II (n = 69)		13	27	29	
	Class III (n = 4)		1	1		2

Appendix 15. Associations between occlusal traits in mixed (Group 2, n = 392) and permanent dentition (Group 3, n = 390).

		Age Year old	OJ ≥ 3.5 mm	OJ ≥ 4.0 mm	OJ ≥ 5.0 mm	OB ≥ 3.5 mm	OB ≥ 4.0 mm	OB ≥ 5.0 mm	Anterior cross-bite	Posterior cross-bite	Scissor bite	Crow-ding
Symmetrical	**Molar Cl II**	7–10	<0.001	<0.001	<0.001	0.021	0.012	0.010		0.035		0.015
		17–21	<0.001	0.003	< 0.001			<0.001		0.028	0.002	
	Canine Cl II	7–10										
		17–21		0.002	<0.001						0.013	
	Molar Cl III	7–10										
		17–21							<0.001	0.002		
Asymmetrical	**Molar Cl II**	7–10	0.050			0.032	0.016	0.004				
		17–21	<0.001	<0.001		<0.001					<0.001	
	Canine Cl II	7–10	0.001	0.003	<0.001		0.050	0.025				0.018
		17–21	0.004	0.017			0.025					
	Molar Cl III	7–10										
		17–21								<0.001		0.012
	Canine Cl III	7–10								0.040		0.049
		17–21							0.004			
OJ ≥ 3.5 mm		7–10							0.004			
		17–21				<0.001						
Posterior crossbite		7–10										
		17–21	0.001	0.001	0.021	<0.001	<0.001					
Scissor bite		7–10										
		17–21	0.004	<0.001		0.001	< 0.001					<0.001

Appendix 16. Occlusal traits and the mean ± standard deviation for mandibular movements (MMO, LMMr, LMMl, PMM) in the mixed dentition (n = 392).

	MMO		LMMr		LMMl		PMM	
	With OT	Without OT	With OT	Without OT	With OT	Without OT	With OT	Without OT
Molar Cl I	49.2 ± 5.2 (n=225)	49.1 ± 4.6 (n=166)	11.1 ± 2.5 (n=225)	11.5 ± 2.0 (n=167)	10.7 ± 2.3 (n=225)	11.0 ± 2.0 (n=167)	**7.1 ± 2.4 (n=225)**	**8.0 ± 2.2* (n=164)**
Molar Cl II	49.8 ± 5.1 (n=86)	49.0 ± 4.9 (n=305)	11.6 ± 2.3 (n=86)	11.2 ± 2.3 (n=306)	11.2 ± 2.1 (n=86)	10.7 ± 2.2 (n=306)	**8.6 ± 2.2 (n=85)**	**7.2 ± 2.3* (n=304)**
Molar Cl III	50.3 ± 4.1 (n=6)	49.1 ± 5.0 (n=386)	11.0 ± 3.5 (n=6)	11.3 ± 2.3 (n=386)	11.2 ± 2.6 (n=6)	10.8 ± 2.2 (n=386)	7.8 ± 2.9 (n=6)	7.5 ± 2.3 (n=386)
Molar end to end	48.8 ± 4.7 (n=211)	49.6 ± 5.2 (n=180)	11.3 ± 2.2 (n=212)	11.1 ± 2.5 (n=180)	10.8 ± 2.2 (n=212)	10.9 ± 2.1 (n=180)	7.5 ± 2.2 (n=210)	7.5 ± 2.5 (n=179)
Canine Cl I	48.9 ± 5.0 (n=288)	49.8 ± 4.9 (n=103)	11.2 ± 2.3 (n=289)	11.5 ± 2.3 (n=103)	10.8 ± 2.2 (n=289)	11.0 ± 2.1 (n=103)	**7.2 ± 2.3 (n=286)**	**8.4 ± 2.1* (n=103)**
Canine Cl II	50.8 ± 6.2 (n=14)	49.1 ± 4.9 (n=377)	**12.6 ± 2.6 (n=14)**	**11.2 ± 2.3* (n=378)**	11.6 ± 2.2 (n=14)	10.8 ± 2.2 (n=378)	**9.4 ± 1.4 (n=14)**	**7.4 ± 2.3* (n=375)**
Canine Cl III	47.6 ± 3.0 (n=9)	49.2 ± 5.0 (n=382)	11.3 ± 2.3 (n=9)	11.3 ± 2.3 (n=382)	10.4 ± 2.4 (n=9)	10.8 ± 2.2 (n=382)	**5.8 ± 1.6 (n=9)**	**7.5 ± 2.3* (n=382)**
Canine end to end	49.3 ± 5.0 (n=163)	49.0 ± 4.9 (n=228)	11.3 ± 2.2 (n=163)	11.3 ± 2.4 (n=229)	10.8 ± 2.2 (n=163)	10.9 ± 2.2 (n=229)	**7.8 ± 2.4 (n=162)**	**7.3 ± 2.3* (n=227)**
OJ ≥ 3.5 mm	49.4 ± 5.3 (n=146)	49.0 ± 4.8 (n=245)	11.1 ± 2.5 (n=147)	11.3 ± 2.2 (n=245)	11.1 ± 2.0 (n=147)	10.7 ± 2.2 (n=245)	**8.7 ± 2.1 (n=144)**	**6.8 ± 2.2* (n=245)**
Negative OJ (< 0)	48.4 ± 3.5 (n=11)	49.2 ± 5.0 (n=380)	12.1 ± 1.8 (n=11)	11.2 ± 2.3 (n=381)	11.5 ± 1.3 (n=11)	10.8 ± 2.2 (n=381)	**6.0 ± 1.9 (n=11)**	**7.5 ± 2.3* (n=378)**
OB ≥ 3.5 mm	**49.9 ± 5.1 (n=183)**	**48.5 ± 4.8* (n=208)**	11.1 ± 2.3 (n=183)	11.4 ± 2.4 (n=209)	10.7 ± 2.3 (n=183)	10.9 ± 2.0 (n=209)	**7.8 ±2.3 (n=182)**	**7.2 ± 2.3* (n=207)**
Negative OB (< 0)	**44.3 ± 2.6 (n=6)**	**49.2 ± 4.9* (n=385)**	11.0 ± 0.6 (n=6)	11.3 ± 2.3 (n=386)	11.3 ± 1.0 (n=6)	10.8 ± 2.2 (n=386)	7.2 ± 1.3 (n=6)	7.5 ± 2.3 (n=383)
Crossbite	**48.6 ± 5.1 (n=47)**	**49.2 ± 4.9* (n=344)**	11.5 ± 2.8 (n=47)	11.2 ± 2.3 (n=345)	11.3 ± 2.0 (n=47)	10.8 ± 2.2 (n=345)	7.4 ± 2.1 (n=47)	7.5 ± 2.4 (n=342)
Scissor bite	**56.5 ± 6.8 (n=6)**	**49.0 ± 4.8* (n=385)**	13.0 ± 2.4 (n=6)	11.2 ± 2.3 (n=386)	11.7 ± 2.7 (n=6)	10.8 ± 2.2 (n=386)	7.3 ± 2.2 (n=6)	7.5 ± 2.3 (n=383)

*Statistically significant difference between children with certain occlusal traits compared with those without the corresponding occlusal trait ($p < 0.05$).

ORIGINAL PUBLICATIONS

PUBLICATION
I

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ORIGINAL ARTICLE

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Occlusal traits of 4–5-year-old Estonians. Parents' perception of orthodontic treatment need and satisfaction with dental appearance

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Abstract

This study aims to evaluate the prevalence of occlusal traits and to assess parents'/caregivers' satisfaction with child's dental appearance and perception of orthodontic treatment need in 4–5-year-old Estonians. Clinical records and plaster casts of 390 children (190 girls and 200 boys, mean age 4.7 years, range 4–5 years) were analyzed. Assessed occlusal traits included deciduous canine and second molar sagittal relationship, overjet, overbite, crowding, midline diastema, crossbite, and scissor bite. Parents'/caregivers' opinions regarding their child's teeth were determined with a questionnaire. The most prevalent occlusal traits were symmetrical sagittal relationship in deciduous canines (78.2%) and molars (75.1%), Class I sagittal relationship in deciduous canines (69.7%) and midline diastema (67.7%). Asymmetrical sagittal canine relationship was registered in 21.8% deciduous canines and in 24.9% second deciduous molars. Parents'/caregivers' perceived orthodontic treatment need was related to Class III sagittal relationship in canines, increased overjet and overbite, negative overbite, and crossbite. Prevalence of most occlusal traits in Estonian children were in line with those reported in neighboring countries. Parents/caregivers were well able to observe occlusal traits that deviated from acceptable occlusion.

KEYWORDS

occlusal traits, perception, satisfaction, treatment need

1 | INTRODUCTION

Childhood is an important period in growth and development of the craniofacial area and teeth. Fully erupted deciduous dentition provides prognostic features from the standpoint of the future development of permanent dentition. The benefit of guiding interceptive interventions and preventive measures in deciduous and mixed dentition has been debated for several decades (Bishara, Hoppens, Jakobsen, & Kohout, 1988; Freeman, 1977; Hixon, 1968; Lavelle, 1976; Leighton, 1970; Sonnesen, Bakke, & Solow, 2001; Thilander, Rubio, Pena, & de Mayorga, 2002). Marked individual variation in growth and development of the jaw, however, complicates the prognosis of occlusal development (Amini, Hamedi, Haji Ghadimi, & Rakhshan, 2017; Horowitz & Hixon, 1966; Leighton, 1975; Solow, 1980; Thilander, 2009).

We declare of originality of our authorship of this manuscript and assure of any conflict of interest.

Moorrees (1959) has provided a baseline analysis of longitudinal dental development between ages 3 and 18. Cross-sectional studies of occlusal traits in different age groups give an overall picture of dental development in the population and assist in recognizing the individuals in need of closer follow-up (Brunelle, Bhat, & Lipton, 1996; Thilander, Pena, Infante, Parada, & de Mayorga, 2001).

Nevertheless, it has recently been shown that, in addition to secular trends that influence dental development, there are also population-specific occlusal traits (Eskeli et al., 2016; Kerosuo, Laine, Nyyssonen, & Honkala, 1991).

This study is the third in a series of cross-sectional investigations analyzing the prevalence of occlusal traits in Estonians between the ages of 4 and 21 years.

The aims of this study were to evaluate

- The distribution of occlusal traits in Estonian 4–5-year-olds.
- Parents'/caregivers' satisfaction with their children's dental appearance and their perceptions on orthodontic treatment need in this age group.

Work hypotheses of this study were that

- The prevalence and types of occlusal traits in Estonia do not differ significantly from those in neighboring countries in the age group of 4–5 years.
- Occlusal traits observed by parents/caregivers differ from those observed by orthodontic professionals.

2 | SUBJECTS AND METHODS

2.1 | Data source

A 95% confidence interval around an estimate (±2.5% of the estimate) was specified for sample size calculation. In the sampling, a multistage stratified cluster design was implemented. Recruitment of 4–5-year-old children was started in March 2011 and completed in January 2012. All of the 4–5-year-old children from 11 selected kindergartens—five in North Estonia, four in Central Estonia, and two in Southwest Estonia—were invited to participate in the study.

The number of invited children was 467. A total of 77 children were excluded for following reasons: (a) 41 children were not in kindergarten on the examination days, (b) 29 parents did not agree their child to participate in the clinical study (c) six children were too afraid to participate in the clinical study, and (d) one child had cleft lip and palate. Thus, the final sample consists of 390 children (190 girls and 200 boys, mean age 4.7 years, range 4–5 years). The sampling procedure is illustrated in Figure 1.

Prior to the study, a written description of the study protocol was given to all parents/caregivers. All parents/caregivers signed an informed consent form. The study protocol was approved by the Ethics Review Committee on Human Research of the University of Tartu (Protocol No. 186T-24).

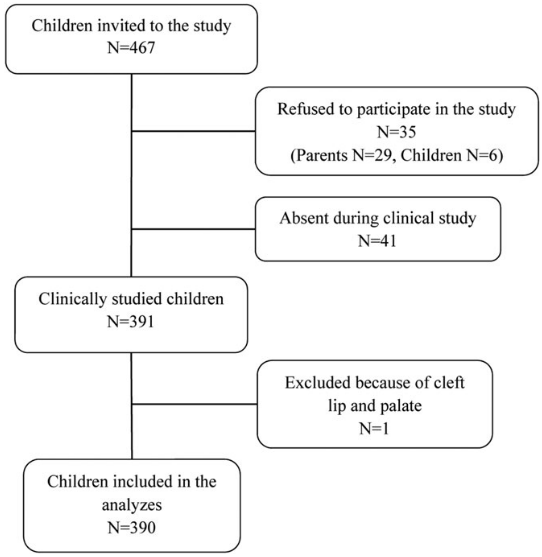

FIGURE 1 The flow chart describing refining of the final sample

2.2 | Registration of occlusal traits

The following occlusal traits were registered clinically in centric occlusion by one orthodontist (Examiner 1): (a) sagittal relationships in deciduous canines and second molars separately for right and left side, (b) overjet (OJ), (c) overbite (OB), (d) crossbite, and (e) scissor bite.

To obtain centric occlusion, a child was asked to open mouth only slightly. The orthodontist gently verified that mandible was relaxed, then the child was asked to bite together.

The examination was carried out in the kindergarten's medical office using a dental mirror, probe, pencil (0.3 mm), and millimeter ruler (with 0.5 mm intervals; Dentaurum 042-751 Münchner Modell). The clinical study was complemented with alginate impressions for plaster casts. Preshaped bite registration wax was softened in warm water bath and placed against the upper dental arch; relaxed mandible was gently guided into centric occlusion to get indentations of cusps of lower teeth into registration wax.

Examiners 1 and 2 registered three features from the plaster casts in consensus: (a) end-to-end relationship of the deciduous canines and second molars, separately for the right and left side, (b) crowding, and (c) diastemas between central incisors.

Registration of the occlusal traits was based on international standards (Brunelle et al., 1996; Horowitz & Hixon, 1966; Moorrees, 1959). A detailed description of the criteria has been presented previously (Sepp, Saag, Svedström-Oristo, Peltomäki, & Vinkka-Puhakka, 2017).

2.3 | Questionnaire

Opinions regarding children's general dental health, tooth alignment, dental appearance, and orthodontic treatment need were collected with a questionnaire filled in at home by parents/caregivers. More than one answer per question was allowed. The questionnaire was modified from one used in a previous study (Pietilä & Pietilä, 1996).

2.4 | Reliability and statistical analysis

Twenty-two children were reexamined clinically by Examiner 1 after a 1-week interval before the intended study. The reliability was very good ($r > 0.99$). A total of 122 plaster casts were reexamined for calibration after 1 month by Examiners 1 and 2 together. The reliability was very good ($r > 0.98$). Chi^2 and Fisher's exact test (where necessary) were used to compare the frequencies of occlusal traits (IBM SPSS v.20 software for Windows [IBM Corp, Armonk, NY, USA]). p values of less than 0.05 were considered statistically significant. The test–retest was calculated using Pearson's correlations ($r = 0.72$, $p < 0.01$).

3 | RESULTS

In the current study, there were a total of 28 children (7.2%) with symmetrical flush terminal plane and Class I in deciduous canines, OJ 1–3 mm and OB 1–3 mm, no crowding, scissor bite or crossbite. Of their parents/caregivers, 23 (85.2%) were satisfied with the alignment of teeth.

3.1 | Occlusal traits

The most prevalent occlusal traits were symmetrical relationship in deciduous canines (78.2%) and molars (75.1%), Class I sagittal relationship in deciduous canines (69.7%) and midline diastema (67.7%) (Table 1).

Asymmetrical sagittal relationship in deciduous canines was found in 21.8% and in second deciduous molars in 24.9% of the examinees (Figure 2). Children with asymmetric end-to-end sagittal relationship in canines had statistically significantly more crossbites compared with children with symmetric end-to-end sagittal relationship ($p < 0.01$).

The OJ ranged from −4.0 mm to 7.0 mm (mean 2.1 mm, SD 1.4) and the OB from −5.0 mm to 6.5 mm (mean 2.7 mm, SD 1.7) (Figure 3). A statistically significant gender difference was found in OJ. Boys had on average larger OJ than girls (boys 2.2 ± 1.4 vs. girls 1.9 ± 1.4, $p < 0.01$), and there was a trend of more boys with increased OJ (OJ ≥ 3.5 mm) compared with girls ($p = 0.06$).

Of children with negative OJ (OJ < 0 mm), 24.2% had Class III sagittal relationship in canines unilaterally or bilaterally. OJ and OB were statistically significantly larger in children with distal terminal plane (OJ 1.8 vs. 2.6, OB 2.4 vs. 3.3, $p < 0.01$) compared with those with Class II sagittal relationship in canines (OJ 2.0 vs. 3.1, OB 2.6 vs. 4.0, $p < 0.01$), end-to-end canine sagittal relationship (OJ 1.8 vs. 2.5, OB 2.5 vs. 3.0, $p < 0.01$), and those without crossbite (OJ 2.2 vs. 1.2, OB 3.1 vs. 1.2, $p < 0.01$).

The midline diastema ranged from 0.1 to 6.0 mm. In the lower arch, it was statistically significantly smaller in children with distal terminal plane of deciduous molars (0.5 vs. 0.7, $p = 0.02$), Class III sagittal relationship in canines (0.6 vs. 1.1, $p = 0.01$), and those with crossbite (0.6 vs. 0.8, $p = 0.03$).

TABLE 1 Prevalence of occlusal traits in 4–5-year-old Estonian children (N = 390)

Occlusal trait	Prevalence (%; N = 390)
Deciduous molar relationship	
Mesial terminal plane	47.9
Flush terminal plane	42.8
Distal terminal plane	33.6
Symmetric	75.1
Asymmetric	24.9
Canine relationship	
Class I	69.7
End-to-end	42.8
Class II	5.6
Class III	3.8
Symmetric	78.2
Asymmetric	21.8
Horizontal relationship	
Overjet ≥ 3.5 mm	15.6
Overjet < 0 mm	2.3
Vertical relationship	
Overbite ≥ 3.5 mm	38.7
Overbite < 0 mm	3.1
Transversal relationship	
Posterior crossbite	17.4
Scissor bite	0.5
Midline diastema	
Upper and lower arch	34.9
Maxillary	46.9
Mandibular	55.6
Crowding	
Upper and lower arch	0.0
Maxillary	0.0
Mandibular	0.3

Posterior crossbite was observed in 6.7% on the right side, in 4.3% on the left side, and in 6.4% on both sides. One child had a scissor bite on the right and one on the left side. None of the children had bilateral scissor bite.

3.2 | Parents'/caregivers' satisfaction

The children whose parents/caregivers were satisfied with the arrangement of their child's teeth had significantly less scissor bite ($p = 0.02$), increased OB ($p = 0.01$), negative OB ($p < 0.01$), and Class III sagittal relationship in canines ($p = 0.05$), compared with children whose parents were dissatisfied with the arrangement of their child's teeth (Table 2).

3.3 | Parents'/caregivers' opinions on orthodontic treatment need in 4–5-year-old children

All parents whose child had Class III sagittal relationship in canines, increased OJ (OJ threshold ≥4 mm) and OB (OB threshold ≥4 mm),

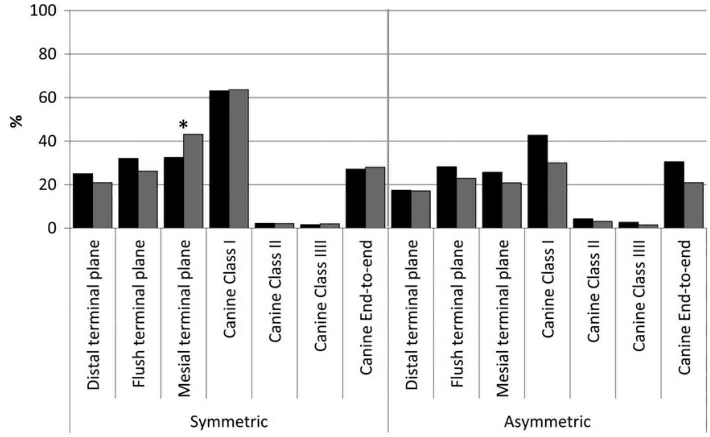

FIGURE 2 Distribution of sagittal relationship of the second deciduous molars and deciduous canines in 4–5-year-old Estonian girls (black) and boys (gray) (N = 390). Gender difference was present only for mesial terminal plane (*p < 0.05)

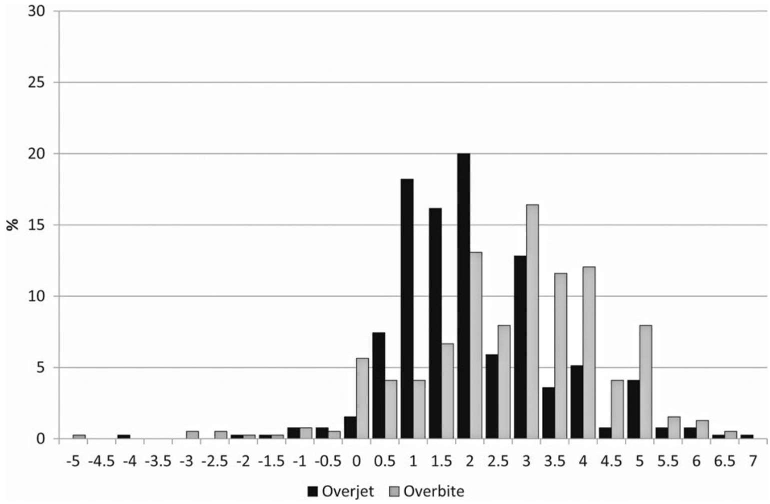

FIGURE 3 The range of overjet (black) and overbite (gray) in 4–5-year-old children in Estonia (N = 390)

negative OB, and crossbite thought their child was in need of orthodontic treatment.

Reduction in the amount of caries was highlighted most often by parents/caregivers as a reason for orthodontic treatment (52.5%). They were also more likely to want improvement in function if the children had crossbite (27.0% vs. 16.0%, p = 0.01) (Table 3).

4 | DISCUSSION

Data on distribution of occlusal traits, on parents'/caregivers' satisfaction with dental appearance, and their opinions on orthodontic treatment need in 4–5-year-old children have been lacking in Estonia.

In Estonia, the prevalence of mesial terminal plane was much higher than in Finland (47.9% vs. 19.1%, respectively) (Keski-Nisula, Lehto, Lusa, Keski-Nisula, & Varrela, 2003). Variability in deciduous molar sagittal relationship may be partly related to subjectivity in its definition. Indeed, the canine sagittal relationship has proved to be more reliable than that of molars. Although the prevalence of Class III sagittal relationship in canines was lower in Estonia than in Sweden (3.8% vs. 9.0%) (Dimberg, Lennartsson, Söderfeldt, & Bondemark, 2013), it was higher than in Finland (1.5%) (Keski-Nisula et al., 2003). However, these values may possibly include some canine Class I relationship because all the occlusal traits in our study were assessed using central occlusion as the reference. In fact, at the age of 4–5 years, ongoing development of temporomandibular joints makes definition of centric relation more or less unreliable (Karlo et al., 2010).

Distribution of symmetric and asymmetric sagittal molar relationships in Estonian children was in line with that of Finnish children (Keski-Nisula et al., 2003).

In our study, the prevalence of posterior crossbite was significantly higher in children with asymmetrical than symmetrical sagittal relationship. Prevalence of bilateral crossbite in Estonians was equal to that of Swedes (Dimberg et al., 2013) but higher than that of Finnish children (Keski-Nisula et al., 2003). However, the prevalence of negative OJ in this study was similar to that in Finland as well as Sweden (Dimberg et al., 2013; Keski-Nisula et al., 2003).

TABLE 2 Prevalence of occlusal traits and parents'/caregivers' opinions regarding their children's dental health and the appearance and alignment of their teeth (*N* = 390)

	Girl		Boy		Total	
	N	%	*N*	%	*N*	%
Prevalence of occlusal traits						
Posterior crossbite	31	16.3	37	18.5	68	17.4
Overjet <0 mm	6	3.2	3	1.5	9	2.3
Overbite <0 mm	5	2.6	7	3.5	12	3.1
Overjet ≥4 mm	18	9.5	29	14.5	47	12.1
Overbite ≥4 mm	54	28.4	53	26.5	107	27.4
Canine Class III	8	4.2	7	3.5	15	3.8
Satisfaction with child's dental health						
Very satisfied	44	23.2	25	12.5	69	17.7
Satisfied	112	58.9	120	60.0	232	59.5
I do not care	1	0.5	2	1.0	3	0.8
Dissatisfied	26	13.7	40	20.0	66	16.9
Not satisfied at all	5	2.6	11	5.5	16	4.1
I do not know	2	1.1	2	1.0	4	1.0
Total	190	100.0	200	100.0	390	100.0
Satisfaction with the alignment and appearance of child's teeth						
Very satisfied	40	21.1	29	14.5	69	17.7
Satisfied	114	60.0	143	71.5	257	65.9
Dissatisfied	21	11.1	17	8.5	38	9.7
Unhappy	0	0.0	1	0.5	1	0.3
I do not know	14	7.4	6	3.0	20	5.1
No answer	1	0.5	4	2.0	5	1.3
Total	190	100.0	200	100.0	390	100.0
Desire for orthodontic treatment						
Definitely not	18	9.5	14	7.0	32	8.2
No, I do not think so	119	62.6	125	62.5	244	62.6
Yes, I think so	36	18.9	33	16.5	69	17.7
Yes, definitely	1	0.5	3	1.5	4	1.0
No answer	16	8.4	25	12.5	41	10.5
Total	190	100.0	200	100.0	390	100.0

The prevalence of midline diastema in 4–5-year-olds (67.7%) reflected that of 7–10-year-old Estonians (73.0%) (Sepp et al., 2017). This finding conforms with the idea that the structure of the frenulum influences the position of central incisors.

Estonian children had a lower prevalence of increased OJ (OJ > 4 mm) compared with Finnish and Swedish children (Dimberg et al., 2013; Keski-Nisula et al., 2003). Instead, prevalence of increased OB (OB > 4 mm) (27.0%) of Estonian children was in line with that of Finnish children (34.0%) (Keski-Nisula et al., 2003).

TABLE 3 The reasons for parents' desire for orthodontic treatment in 4–5-year-old Estonian children (*N* = 390)

Reason	*N*	%
To reduce the amount of caries	84	52.5
To improve dental appearance	27	16.9
To improve occlusal function	21	13.1
Other reason	17	10.6
To facilitate cleaning	11	6.9
Total	160	100.0

There was no crowding in any of the studied 4–5-year-old Estonians. This finding is contrary to the situation in Finland, where crowding in the maxilla has been found in 11.6% and in the mandible in 38.9% of children (Keski-Nisula et al., 2003). The difference was clear, although crowding was measured on plaster casts in both of these studies.

Benefit of orthodontic treatment is estimated by a dentist using professional criteria. Patients/parents/caregivers make their own observations, which are equally important in judgment of treatment need and outcome. Therefore, it is important to know how parents/caregivers, as laypersons, observe dentition and how critical they are (Ryan & Cunningham, 2018).

What this paper adds?

- Prevalence of most occlusal traits in Estonian 4–5-year-olds is in line with those reported in neighboring countries, except for negative OB, increased OJ, and lack of crowding.

- The most prevalent occlusal traits in Estonian 4–5-year-olds are symmetrical sagittal relationship in deciduous canines and molars, Class I sagittal relationship in deciduous canines, mesial terminal plane in deciduous second molars, and midline diastema.
- With regard to dental health and appearance, more than four out of five parents/caregivers are satisfied. Dissatisfied parents seem to focus on occlusal traits like negative OB, deep bite, and Class III relationship in canines.
- The hypothesis that parents/caregivers do not pay attention to professionally important traits in their child's dentition is rejected.

Why this paper is important for dentists?

- It is important to know that the majority of 4–5-year-old children have occlusal traits that may develop into malocclusion.
- Dental professionals should appreciate parents'/caregivers' observations regarding their child's occlusal traits and functioning of the masticatory system. They seem to be well able to observe occlusal traits and functions that deviate from the so-called "normal."

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PUBLICATION
II

Occlusal traits and orthodontic treatment need in 7- to 10-year-olds in Estonia

Hettel Sepp, Mare Saag, Anna-Liisa Svedström-Oristo, Timo Peltomäki, Heli Vinkka-Puhakka

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ORIGINAL ARTICLE

Occlusal traits and orthodontic treatment need in 7- to 10-year-olds in Estonia

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Abstract

The aim of this study was to evaluate the distribution of occlusal traits and orthodontic treatment need and complexity in Estonian 7- to 10-year-old children. This data provides solid information for planning of orthodontic care. Data of 392 Estonian children (198 girls and 194 boys, mean age 9.0 years, range 7.1–10.4 years) was analysed in this cross-sectional study. Assessed traits included first molar and canine sagittal relationship, overjet, overbite, crowding, midline diastema, crossbite, and scissor bite. Orthodontic treatment need and complexity were assessed using the Index of Complexity, Outcome, and Need. Parents' opinion regarding their child's teeth was determined using a questionnaire. The most prevalent occlusal traits were canine class I sagittal relationship (73.7%), midline diastema (73.0%), molar class I sagittal relationship (57.4%), and overbite ≥3.5 mm (51.8%). According to the Index of Complexity, Outcome, and Need, 64.3% of Estonian elementary school children were in need of orthodontic treatment. Treatment complexity was simple in 12.5%, mild in 38.8%, moderate in 22.7%, difficult in 14.0%, and very difficult in 12.0% of the children. Approximately 66.4% of the parents felt that their child needed orthodontic treatment. This study confirms earlier findings indicating that the most frequent sagittal relationship is class I in the first molars and class I in the canines. However, the sagittal relationship was asymmetric in more than half of the children. Correlation between objectively defined treatment need and parents' desire for treatment was high in Estonia.

KEYWORDS

dental occlusion, ICON, treatment need

1 | INTRODUCTION

Orthodontic treatment has been found to improve oral health-related quality of life (Silvola, Rusanen, Tolvanen, Pirttiniemi, & Lahti, 2012), and demand for orthodontic treatment is growing in many countries. Increased attention is paid to facial and dental appearance, which have been found to affect, for example, social relationships, self-esteem, and conclusions others make on the basis of external characteristics (Kerosuo, Hausen, Laine, & Shaw, 1995; Nisbett & Wilson, 1977; Ritter, Casey, & Langlois, 1991). There are also rare associations between dental features and functions distant to the oral cavity (Giuca, Caputo, Nastasio, & Pasini, 2011; Hultcrantz & Löfstrand-Tideström, 2009; Miles, Vig, Weyant, Forrest, & Rockette, 1996; Monaco et al., 2011; Schütz-Fransson & Kurol, 2008).

In publically funded orthodontic care, data on occlusal traits among 7- to 10-year-olds are essential for planning of treatment strategies. Early mixed dentition stage provides a good time point to consider interceptive orthodontics (Kerosuo, Väkiparta, Nyström, & Heikinheimo, 2008; Sunnak, Johal, & Fleming, 2015). In the oldest children of this age group, clinical signs of skeletal and dental deviations are often clearly visible enabling the further planning of, for example, work force and division of work.

Planning of population-based, cost-effective health services should be founded on data focusing on the target country. Because no data exist on the prevalence of occlusal traits and orthodontic treatment need in Estonia, this study is the first in a series of extensive investigations analysing the prevalence of occlusal traits in children and adolescents from 3 to 21 years of age. Parents' and adolescents' expectations and perceptions concerning orthodontic treatment are also evaluated. The aims of this study were

- to evaluate the distribution of occlusal traits in 7- to 10-year-old children in Estonia and
- to evaluate the objective and subjective need for orthodontic treatment in Estonia.

2 | METHODS

2.1 | Subjects

Recruitment of 7- to 10-year-old children started in November 2009 and was completed in December 2010. A multistage stratified cluster sampling design was implemented. The recruitment took place in four randomly selected elementary schools: one in Tallinn (Northern Estonia), two in Tartu (South Estonia), and one in Pärnu (South-West Estonia). All the second-grade children in selected schools were invited to participate in the study.

Sample size was determined with the aid of a statistical power calculation. The selection of children is illustrated in Figure 1. The final sample consisted of 392 children (198 girls and 194 boys, mean age 9.0 years, age range 7.1–10.4 years). Prior to the study, a written description of the study protocol was given to all children and their parents or guardians. All participants signed an informed consent form, indicating that their participation in the study was voluntary. The study protocol was approved by the Ethics Review Committee on Human Research of the University of Tartu (Protocol No. 186T-24).

2.2 | Clinical examination

Five occlusal traits were registered clinically in centric occlusion, separately for the left and right sides: (a) sagittal relationships of the first molars and canines, (b) overjet, (c) overbite, (d) crossbite, and (e) scissor bite. All clinical examinations were performed by Examiner 1. The examination was carried out in the school's dental office using a dental mirror, probe, pencil (0.3 mm), and millimetre ruler (Dentaurum 042-751 Münchner Modell). Alginate impressions for plaster casts were taken from each child.

2.3 | Plaster casts

Examiners 1 and 2 registered three features from the plaster casts in order to achieve consensus: (a) end-to-end relationship of the first molars and deciduous and permanent canines separately for the right and left side, (b) crowding, and (c) diastemas between central incisors. Registration of the occlusal traits was based on international standards (Brunelle, Bhat, & Lipton, 1996; Horowitz & Hixon, 1966; Moorrees, 1959); a detailed description of definitions is given in Appendix A. Furthermore, using the plaster casts, Index of Complexity, Outcome, and Need (ICON) for orthodontic treatment was assessed according to written instructions (Daniels & Richmond, 2000) by Examiner 1.

2.4 | Reliability

Before the intended study after 1 week, Examiner 1 re-examined clinically 22 children. To assure the validity of ICON assessments, 39 randomly selected plaster casts (10%) were analysed by both Examiner 1 and by an ICON calibrated Examiner 3.

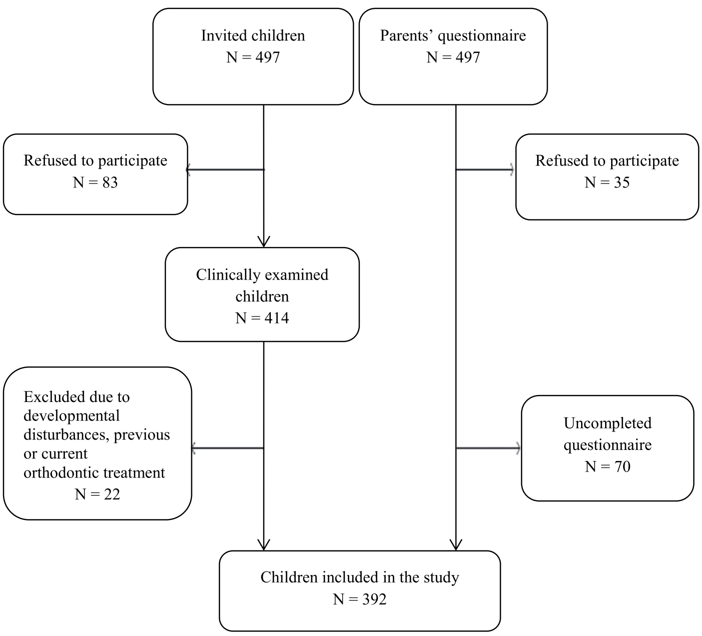

FIGURE 1 Selection of the final study sample

The intraexaminer reliability was good ($r > .97$). The interexaminer reliability varied from moderate ($r = .50$) to good ($r > .93$).

2.5 | Questionnaire

The guardians' opinions regarding a child's general dental health, tooth alignment, dental appearance, and opinion regarding orthodontic treatment need were gathered through five questions (Appendix B). The questionnaire was filled out at home by one of the parents. More than one answer per question was allowed. Questions were modified for this study from similar questions in a previous study (Pietilä & Pietilä, 1996).

2.6 | Statistical analysis

The test–retest (Pearson's and Spearman's correlations) and chi-square test were used to compare the frequencies of specific features (IBM SPSS v.20 software for Windows). p values of less than .05 were considered statistically significant.

3 | RESULTS

3.1 | Occlusal traits among 7- to 10-year-old Estonian children

The most prevalent occlusal traits in Estonian 7- to 10-year-old children were class I canine relationship (73.7%), midline diastema (73.0%), class I molar relationship (57.4%), and increased (≥3.5 mm) overbite (51.8%). The sagittal relationship in canines and molars was asymmetric in a large number of children (33.2% and 35.7%, respectively). The detailed prevalence of occlusal traits is presented in Table 1. There were only 17 children (4.3%, 9 girls and 8 boys) with symmetrical class I canine and molar relationships, overjet and overbite of 1–3 mm, without crowding, scissor bite, crossbite, and negative overbite. The overjet ranged from −1 to 10 mm (mean 3.1 mm, *SD* 1.67). The overbite ranged from −2 to 8.5 mm (mean 3.2 mm, *SD* 1.75). Crowding ranged from 1 to 8 mm in the maxillary and from 0.5 to 8.0 mm in the mandibular arch. The most frequent crowding was 2 mm in the maxillary and 1 mm in the mandibular arch (6.9% and 11.5%, respectively). Compared to boys, girls had 1.6 times greater odds of having crowding, and smaller odds of having canine end-to-end, overjet ≥3.5 mm, and class II molar relationship. The width of the midline diastema was most frequently 2 mm (20.2%) in the maxillary arch (range 0.5–4.5 mm) and 0.5 mm (range 0.5–4.5 mm) in the mandibular arch (6.1%).

TABLE 1 Prevalence of occlusal traits in 7- to 10-year-old Estonian children ($N = 392$)

	Occlusal trait	Prevalence ($N = 392$) %
Canine relationship	Class I	73.7
	Class II	3.6
	End to end	41.6
	Class III	2.3
	Symmetric	66.8
	Asymmetric	33.2
Molar relationship	Class I	57.4
	Class II	21.9
	End to end	54.1
	Class III	1.5
	Symmetric	64.3
	Asymmetric	35.7
Horizontal relationship	Overjet ≥3.5 mm	37.5
	Negative overjet	1.0
Vertical relationship	Overbite ≥3.5 mm	51.8
Transversal relationship	Posterior crossbite	10.2
	Scissor bite	1.5
Spacing	Midline diastema	73.0
	Maxillary	57.7
	Mandibular	15.3
Crowding	Upper and lower arch	49.7
	Maxillary	18.9
	Mandibular	37.9

3.2 | Orthodontic treatment need and complexity of treatment

According to ICON, 64.3% of Estonian 7- to 10-year-olds were in need of orthodontic treatment (ICON score > 43). The scores ranged from 7 to 105 (median score 50), the most frequent score being 44 (11.2%). There were no gender differences in treatment need ($\chi^2(1) = 1.7$, $p = .21$). Distribution of treatment complexity is presented in Table 2.

3.3 | Parents' views and orthodontic treatment need

Approximately 65.6% of the parents were satisfied or very satisfied with their child's dental health. The association between parents' satisfaction and objective treatment need was statistically significant ($\chi^2(3) = 12.83$, $p = .005$). More than half of the parents (53.1%) were satisfied or very satisfied with the alignment and appearance of their child's teeth. Satisfaction with the alignment of a child's teeth and parents' assessment of orthodontic treatment need were statistically significantly associated ($\chi^2(4) = 19.78$, $p < .001$). Approximately 66.4% of parents felt that their child needed orthodontic treatment, mainly for improvement of dental appearance (37.1%), reduction in the amount of caries (23.1%), and ease of cleaning (19.6%). Approximately 56.5% of children whose parents did not want orthodontic treatment were in need of orthodontic treatment according to ICON (Table 3). Parents' opinion regarding treatment need did not differ for girls and boys. A statistically significant association was found between parents' desire to get a child's teeth straightened and treatment need as assessed using ICON ($\chi^2(1) = 5.59$, $p = .022$).

TABLE 2 Distribution of orthodontic treatment complexity in 7- to 10-year-old Estonian children determined with ICON

Complexity	ICON scores	Girls ($N = 198$)		Boys ($N = 194$)		Total ($N = 392$)	
		N	%	N	%	N	%
Simple and mild	<50	112	56.6	89	45.9	201	51.3
Moderate	51–63	40	20.2	49	25.3	89	22.7
Difficult	64–77	28	14.1	27	13.9	55	14.0
Very difficult	>77	18	9.1	29	14.9	47	12.0

Note. ICON = index of complexity, outcome, and need.

TABLE 3 Parents' satisfaction with their child's dental health, and alignment of teeth, and their opinion on treatment need as compared to an assessment using ICON (7- to 10-year-old Estonian children; *N* = 392)

	Treatment need		Total	
	ICON ≤ 43 (*N*)	ICON > 43 (*N*)	*N*	%
Satisfaction with child's dental health				
Very satisfied	11	10	21	5.4
Satisfied	95	141	236	60.2
I don't care	0	1	1	0.3
Somewhat dissatisfied	30	78	108	27.6
Very unsatisfied	2	17	19	4.8
I don't know	0	1	1	0.3
No answer	2	4	6	1.5
Total	140	252	392	100.0
Satisfaction with the alignment of child's teeth				
Very satisfied	8	8	16	4.1
Satisfied	86	106	192	49.0
Somewhat dissatisfied	35	117	152	38.8
Very unsatisfied	3	3	6	1.5
I don't know	7	16	23	5.9
No answer	1	2	3	0.8
Total	140	252	392	100.0
Child needs orthodontic treatment				
Definitely not	2	3	5	1.3
No, I don't think so	45	58	103	26.3
Yes, I think so	63	145	208	53.1
Yes, definitely	17	35	52	13.3
No answer	13	11	24	6.2
Total	140	252	392	100.0

Note. ICON = index of complexity, outcome, and need.

4 | DISCUSSION

This study is the first population-based study registering occlusal traits and orthodontic treatment need among 7- to 10-year-olds in Estonia. The largest ethnic groups in Estonia are Estonians (68% of the population) and Russians (28%); the remaining 4.0% consist of 142 other ethnicities. For practical reasons, sampling was done in cities. Children were randomly selected and can be considered representative of those cities' child population. We have no reason to believe that the situation in the countryside or in other cities is different, because Estonia has neither big cities and slums nor long distances between population centres. Any possible regional differences in Estonia and their possible correlation to the socioeconomic status of families need to be assessed in future studies.

This study confirmed earlier findings, namely, that the most frequent sagittal relationship is class I in the first molars and class I in canines. Worth noting is that at the age of 7- to 10 years, asymmetric sagittal molar and canine relationships were frequent in Estonian children. Asymmetry or laterality (directional asymmetry) is a common finding in many craniofacial structures (Pirttiniemi & Kantomaa, 1992). Decay, early loss of the deciduous teeth, discrepancy in tooth size and quantity, derangements in the temporomandibular joint, or asymmetric habits may create asymmetric occlusal development (Moorrees, 1959; Thilander & Rönning, 1985). Prevalence of class II molar relationship was 21.9%, which is in line with the prevalence reported from other countries, 9.2–28.0% in mixed dentition (Dimberg, Lennartsson, Söderfeldt, & Bondemark, 2013; Lux, Dücker, Pritsch, Komposch, & Niekusch, 2009; Myllärniemi, 1970). In part, the variability may be related to differences in applied criteria and in the interpretation of findings. Most studies have not differentiated between sagittal symmetry and asymmetry. The range of overjet in 7- to 10-year-old Estonian children was similar to that of 9-year-old children in Germany (Lux et al., 2009), but unlike in Germany, there was no difference between boys and girls in Estonia. Compared with Finnish children, Estonian children had a higher prevalence of an increased overjet in mixed dentition (Myllärniemi, 1970). It is possible that Estonian children with an overjet of ≥6 mm would benefit from early orthodontic treatment (Artun & Al-Azemi, 2009; Järvinen, 1978). The recent *Cochrane Review* also concludes that early orthodontic treatment is effective, for example, in reducing the incidence of incisal trauma (Thiruvenkatachari, Harrison, Worthington, & O'Brien, 2013).

The frequency of negative overbite was similar in Estonian and Finnish children but clearly lower than in a Swedish sample of 7-year-olds, where those with erupting incisors had already been excluded from analyses (Dimberg et al., 2013).

Despite the rarity of crossbite and scissor bite, they should be monitored for. Early treatment may prevent development of occlusal dysfunction and asymmetrical growth (Pirttiniemi & Kantomaa, 1992; Thilander, Wahlund, & Lennartsson, 1984).

In the age group of 7- to 10-year-olds, the youngest children were just entering to early mixed dentition, whereas some 10-year-olds already had permanent dentition. Hence, considerations for interseptive procedures range from assisting proper eruption of incisors and first molars to spacing or crowding and skeletal relationships. All dentists face these occlusal traits in yearly dental examinations. In addition, the frequent asymmetric sagittal relationships observed in this study bring additional challenge for orthodontic planning.

In this age group, there exists no generally accepted treatment need index, quick to apply, and use in assessment of plaster casts. Despite the fact that ICON is designed for late-mixed dentitions (Daniels & Richmond, 2000), we used it for assessment of orthodontic treatment need. Its assessments are clearly determined and it also provides data on treatment complexity. The 10 included photographs Aesthetic Component of the Index of Orthodontic Treatment Need (AC/IOTN) represent slightly older children. However, they can easily be used as a reference to the level of dental aesthetics; there is no intention to point out a similar dentition to the one that the child has but to select the photograph with as pleasing an occlusion. As a matter of fact, there is no photograph representing, for example, negative overbite or class III relationship. In the future, the ICON scores will be comparable with those of the older age group of Estonian adolescents. Although ICON is useful in assessing treatment need, it does not assist in planning the timing of treatment, which is an important aspect of paediatric orthodontic care.

Girls seem to pay more attention to their appearance and are more interested in orthodontic treatment than boys (Birkeland, Bøe, & Wisth, 2000; Jung, 2010). In Estonia, parents' opinions were not influenced by the child's gender. Future studies should assess the age at which Estonian children themselves begin to pay attention to occlusal traits and dental appearance.

As determined with ICON, orthodontic treatment need in Estonia is higher than reported in epidemiological studies from Latvia and Finland (Heikinheimo, 1978; Liepa, Urtane, Richmond, & Dunstan, 2003). The expectations and wishes of parents are in line with ICON, partly because the index is sensitive to visible deviations. This study confirms earlier findings (Birkeland et al., 2000; Kiekens, Maltha, van't Hof, & Kuijpers-Jagtman, 2006) that patients' main expectations regarding orthodontic treatment are related to improvement in dentofacial aesthetics. This study fills a significant knowledge gap in oral health in Estonia by providing an overview of dental traits among 7- to 10-year-old children.

5 | CONCLUSION

The present results indicate that

- the most prevalent occlusal traits were class I canine sagittal relationship, midline diastema, class I molar sagittal relationship, and increased overbite;
- more than half of Estonian children had an asymmetrical canine and molar relationship;
- according to ICON, 64.3% of Estonian 7- to 10-year-olds were in need of orthodontic treatment;
- a statistically significant association was found between parents' desire to straighten their child's teeth and treatment need assessed using ICON. Parents' opinion regarding orthodontic treatment need did not differ in a statistically significant way on the basis of the child's gender; and
- the parents' main expectation from orthodontic treatment was improvement in dentofacial aesthetics.

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APPENDIX A

REGISTRATION CRITERIA OF OCCLUSAL TRAITS IN THE CLINICAL EXAMINATION AND FROM THE PLASTER CASTS

A.1. | Sagittal plane

The sagittal relationship of the first permanent molars was registered between perpendicular projections, on the occlusal plane, from the tip of the triangular ridge of the mesiobuccal cusp of the maxillary first permanent molar and the buccal groove of the mandibular first permanent molar.

Molar class I: the triangular ridge articulated in the buccal groove of the mandibular first permanent molar.

Molar class II: the triangular ridge articulated anterior to the mesial groove of the mandibular first permanent molar.

Molar class III: the triangular ridge articulated posterior to the mesial groove of the mandibular first permanent molar.

End to end: the triangular ridge of the mesiobuccal cusp of the maxillary first permanent molar articulated to the triangular ridge of the mesiobuccal cusp of the mandibular first permanent molar.

Molar classes II and III were registered in the accuracy of ≥1/2 cusp width. In cases of obvious tooth migration, no attempt was made to endeavour the original intercuspation. Registration was not done when the first molar was missing.

The sagittal relationship of the canines was measured between perpendicular projections, on the occlusal plane, from the tip of the maxillary canine and the contact point of the mandibular canine and the first deciduous molar or the first premolar.

Canine class I: the tip of the maxillary canine occluded to the distal surface of the mandibular canine.

Canine end to end: the tip of the maxillary canine articulated to the tip of mandibular canines. A deviation of 1 mm or more to the mesial or distal was classified as canine class II or I, respectively.

Canine class III: the tip of the maxillary deciduous canine occluded more than 1 mm posterior to the distal surface of the mandibular canine

In the case of missing canine, the registration was not recorded. No attempt was made to compensate for drift of teeth due to premature extraction or any other reasons.

A.2. | Horizontal plane

The overjet (positive) was measured in 0.5-mm intervals as the horizontal distance, parallel to the occlusal plane, from the most labial surface of the lower central incisors to the most labial point of the incisal edge of the corresponding upper incisors. In case both upper or lower central incisors were missing, the lateral incisor was used.

A negative overjet was measured in 0.5-mm intervals as the horizontal distance, parallel to the occlusal plane from the most labial surface of the upper central incisor to the most labial point of the incisal edge of the corresponding lower central incisors.

A.3. | Vertical plane

The overbite (positive) was measured in 0.5-mm intervals as the distance between the projection of the edge of the most overlapped central incisor on the labial surface of the lower incisors (in centric occlusion) and the incisal edge of the lower incisor.

A negative overbite or open bite was recorded when there existed a vertical space between the upper and lower incisal edges in the centric occlusion. The negative overbite was measured in 0.5 mm intervals from the incisal edge of the lower incisors to the incisal edge of the upper corresponding incisors.

A.4. | Transversal plane

The posterior crossbite was registered in the canine, premolar, and molar area when the buccal cusp of the maxillary tooth occluded lingual to the buccal cusp of the mandibular antagonists (at least one pair of teeth). Teeth in an end-to-end position were registered as crossbite.

A scissor bite was recorded in the premolar and molar area when lingual cusps of maxillary teeth occluded buccally of the buccal surfaces of corresponding mandibular teeth.

A.5. | Crowding

Crowding of the teeth was estimated as total space deficiency (in millimeters) of the anterior teeth (incisors only). The amount of crowding was recorded in the maxillary and mandibular arch as the difference between the total mesio-distal tooth diameter and the arch circumference. The possible influence of growth in arch width was not estimated.

A.6. | Midline diastema

Midline diastema between the central incisors in the upper and lower arch was measured in 0.5-mm intervals between the mesial margin of the right and left incisors on the middle height of the tooth crown.

APPENDIX B

QUESTIONNAIRE

1. How satisfied are you with the dental health of your child?
   Very satisfied/Satisfied/I don't care/Somewhat dissatisfied/Very unsatisfied/I don't know
2. How satisfied are you with the alignment of your child's teeth?
   Very satisfied/Satisfied/Somewhat dissatisfied/Very unsatisfied/I don't know
3. Do you think that your child needs orthodontic treatment?
   Definitely not/No, I don't think so/Yes, I think so/Yes, definitely
4. For what reason would you like to align your child's teeth?
   To improve their appearance/To improve their function/For ease of cleaning/To reduce caries/Other reasons/I don't know
5. Has your child ever worn an orthodontic appliance or is your child wearing one now?
   Yes/No/I don't know

PUBLICATION
III

Occlusal traits, orthodontic treatment need and treatment complexity among untreated 17–21-year-olds in Estonia

Hettel Sepp, Mare Saag, Timo Peltomäki, Heli Vinkka-Puhakka, Anna-Liisa Svedström-Oristo

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ORIGINAL ARTICLE

Occlusal traits, orthodontic treatment need and treatment complexity among untreated 17–21-year-olds in Estonia

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ABSTRACT

Objective: To analyze data on occlusal traits, orthodontic treatment need and treatment complexity in orthodontically untreated 17–21-year-old Estonians.

Materials and methods: Clinical records and plaster casts of 390 untreated young adults (219 females and 171 males, mean age 18.5 years, range 17–21 years) were analyzed. Assessed occlusal traits included first molar and canine sagittal relationship, overjet, overbite, crowding, midline diastema, crossbite and scissor bite. The Index of Complexity, Outcome and Need (ICON) was used to assess orthodontic treatment need and complexity. Participants' opinions regarding their teeth were determined with a questionnaire.

Results: The most prevalent occlusal traits were Class I sagittal relationship in canines (76%) and molars (70%), crowding (51%), overbite $\geq$3.5 mm (48%), the end-to-end sagittal relationship in canines (48%) and overjet $\geq$3.5 mm (47%). Antero-posterior asymmetry was common both in canines (39%) and molars (37%). According to ICON, 36% of participants had orthodontic treatment need.

Conclusions: Desire for orthodontic treatment was associated with crowding and increased overjet, and with no gender difference, participants' main expectation of treatment was an improvement in dentofacial aesthetics. Treatment needs determined with ICON was moderate and in line with the participants' desire for orthodontic treatment.

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KEYWORDS
ICON; occlusal features; questionnaire; self-perception

Introduction

In the past, healthy and attractive teeth were not considered an obvious or inseparable aspect of social communication among Estonians. Over the last years, interest in dental aesthetics has grown, and consequently, the demand for orthodontic treatment has increased among the population. An assessment of self-perceived treatment need has also become an important part of the screening process, and clinicians' sensitivity towards patient expectations influence the mutual interaction [1–3].

Studies on the prevalence of occlusal traits, and professionally assessed and self-perceived orthodontic treatment need support the planning and provision of public orthodontic services for those most in need. In addition, epidemiologic studies on the prevalence of occlusal traits at different developmental stages and within various population groups provide data on developmental trends and aetiology of malocclusions [4–9]. This study is the second in a series of investigations analyzing the prevalence of occlusal traits in Estonians between the ages of 3 and 21 years.

The aims of this study were

- to evaluate the distribution of occlusal traits in 17–21-year-olds with no history of orthodontic treatment
- to evaluate objective and subjective treatment need and complexity of orthodontic treatment in this age group.

Subjects and methods

Recruitment of 17–21-year-old young adults was begun in November 2009 and completed in January 2011. In the sampling, a multistage stratified cluster design was implemented. All twelfth-grade students from four randomly selected high schools – one in northern Estonia, two in central Estonia and one in Southwestern Estonia – were invited to participate in the study. The initial number of young adults invited to take part was 548. Young adults who were not in school on the examination day were offered a second-time point for examination. The sampling procedure and exclusion of participants are illustrated in Figure 1. Among the excluded young adults, 150 (27%) had previous or currently ongoing orthodontic treatment.

Six occlusal traits were registered clinically by Examiner 1 in centric occlusion, on the left and right sides separately: 1) sagittal relationships in canines and 2) first molars 3) overjet, 4) overbite, 5) crossbite and 6) scissor bite. The examination was carried out in the school's dental office using a dental

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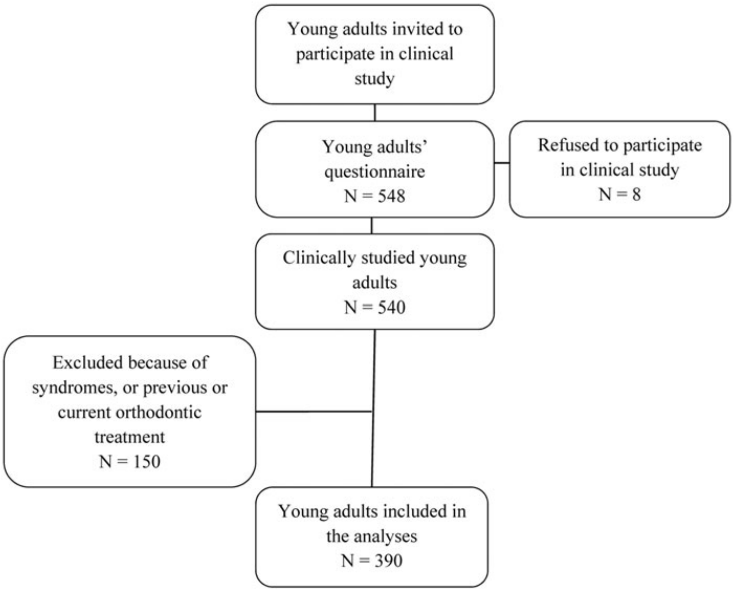

Figure 1. Selection of the final study sample.

mirror, probe, pencil (0.3 mm) and millimetre ruler (Dentaurum 042-751 Münchner Modell). The clinical study was complemented with alginate impressions for plaster casts.

Four more features were verified from the plaster casts jointly by Examiner 1 and Examiner 2: 1) an end-to-end relationship in canines and 2) first molars, on the left and right sides, 3) crowding and 4) diastemas between central incisors. Registration of the occlusal traits was based on international standards [10–12]. A detailed description of the criteria has been presented previously [13]. Orthodontic treatment need and complexity were assessed from the plaster casts using the Index of Complexity, Outcome and Need [14]. A threshold score of more than 43 indicates treatment need. Scores <29 indicate easy, 29–50 mild, 51–63 moderate, 64–77 difficult and >77 very difficult treatment complexity. Participants' opinions regarding their dental health, alignment of teeth, dental appearance and orthodontic treatment need were collected with a questionnaire [15].

Prior to the study, a written description of the study protocol was given to all participants. All participants signed an informed consent form indicating that their participation in this study was voluntary. The study protocol was approved by the Ethics Review Committee on Human Research of the University of Tartu (Protocol No. 186T-24).

Reliability and statistical analyses

A 95% confidence interval around an estimate (±2.5% of the estimate) was specified for sample size calculation. Before the study, 22 volunteer students were examined clinically and re-examined after a one-week interval by Examiner 1. Furthermore, the four features verified from the 22 plaster casts were re-assessed after a one-month interval by Examiners 1 and 2 for consensus. The intra-examiner reliability was good ($r > 0.98$ and $r > 0.97$, respectively). To evaluate the ICON assessments, 39 (10%) randomly selected plaster casts were analyzed twice by Examiner 1 and by an ICON-calibrated Examiner 3. The inter-examiner reliability was good ($r > 0.72$).

The Chi-square test was used to compare the frequencies of occlusal traits. Exploring gender differences, logistic regression was used (IBM SPSS v.20 for Windows (IBM Corp, Armonk, NY, USA)). *p* Values of less than .05 were considered statistically significant. The test–retest was calculated using Pearson's correlations ($r = 0.72$, $p < .001$).

Results

The most prevalent occlusal traits were Class I sagittal relationship in canines (76%) and molars (70%), crowding (52%), overbite $\geq$3.5 mm (48%), an end-to-end sagittal relationship in canines (48%) and overjet $\geq$3.5 mm (47%). Compared with males, females had 1.7 times greater odds of having an end-to-end relationship in canines ($p = .011$). The detailed distribution of occlusal traits is presented in Table 1.

Antero-posteriorly asymmetrical canine and molar sagittal relationship was found in 39% and 37% of participants, respectively. An asymmetrical Class II in molars was associated with crowding [$\chi^2 = 4.27$, df $=1$, $p = .041$] and with scissor bite [$\chi^2 = 21.87$, df $=1$, $p = .000$]. Satisfied participants had less crowding in the lower arch compared with those who were dissatisfied [0.72 vs 1.1, $t(366) = -2.57$, $p = .011$]; also crowding in the upper arch was substantially less than among dissatisfied participants [0.32 vs 0.73, $t(366) = -2,87$, $p = .005$]. Dissatisfied participants had larger overjet than

Table 1. Prevalence of occlusal traits in Estonian 17–21-year-olds ($n = 390$).

	Occlusal trait	Prevalence ($N = 390$) %
Canine relationship	Class I	76
	Class II	7
	End-to-end	48
	Class III	3
	Symmetric	62
	Asymmetric	38
Molar relationship	Class I	70
	Class II	21
	End-to-end	29
	Class III	13
	Symmetric	63
	Asymmetric	37
Horizontal relationship	Overjet $\geq$3.5 mm	47
	Negative overjet	1
Vertical relationship	Overbite $\geq$3.5 mm	48
Transversal relationship	Posterior crossbite	27
	Scissor bite	11
Spacing	Midline diastema	7
	• maxillary	5
	• mandibular	1
Crowding	Upper and lower arch	51
	• maxillary	30
	• mandibular	22

Table 2. Distribution of orthodontic treatment complexity in Estonian 17–21-year-olds ($n = 390$) determined with ICON.

ICON		Girls		Boys		Total	
Complexity grade	Score range	N	%	N	%	N	%
Easy/Mild	<50	168	76.7	122	71.4	290	74.4
Moderate	51–63	36	16.4	27	15.8	63	16.1
Difficult	64–77	12	5.5	17	9.9	29	7.4
Very difficult	>77	3	1.4	5	2.9	8	2.1
Total		219	100.0	171	100.0	390	100.0

satisfied ones [T (366) = –4.46, $p < .001$]. For overjet, 4.0 mm was the threshold for significantly increased dissatisfaction.

The ICON scores ranged from 7 to 87 (median 31). According to ICON, 36% of 17–21-year-olds were in need of orthodontic treatment; no gender difference was found [$\chi^2 = 0.96$, df =1, $p = .333$]. Distribution of treatment complexity is presented in Table 2. In this age group, treatment complexity was easy in 45%, mild in 30%, moderate in 16%, difficult in 7% and very difficult in 2%. A total of 44% of the participants wanted orthodontic treatment. A statistically significant positive association was found between participants' desire to get their teeth straightened and orthodontic treatment needs determined with ICON [χ^2 (3) = 19.33, $p = .000$]. Self-perceived orthodontic treatment need did not differ between genders [χ^2 (3) = 3.76, $p = .288$] (Table 3). Participants wanted orthodontic treatment to improve their dental appearance (37%), diminish their risk for caries (9%), improve function (5%) and facilitate teeth cleaning (3%).

Discussion

The aim of this study was to analyze the distribution of occlusal traits and to evaluate objective and subjective orthodontic treatment need among untreated 17–21-year-olds. As expected, the most frequent occlusal traits were Class I in canines and molars. Interestingly, asymmetrical sagittal canine and the molar relationship was found in more than one in three participants. This finding is in line with those of other recent studies focusing on antero-posterior asymmetries at various stages of dental development [16–18].

The prevalence of crowding was 10% lower than in neighbouring Finland [19]. This, and the higher frequency of molar rather than canine Class III relationships may indicate higher rates of early extractions of deciduous molars, presumably due to caries or crowding. The prevalence of crossbite and scissor bite was also higher than expected.

The final sample represents 71% of the originally invited 17–21-year-olds who had not had availability of orthodontic services or the possibility of treatment. It is also plausible that some of them were not interested in treatment, or their malocclusion had not been severe enough to fulfil the selection criteria. The sample covers 1% of the target cohorts in Estonia. Thus, the results give an estimate of the allocation of orthodontic care; this estimate is more likely to underestimate rather than overestimate occlusal deviations and treatment need.

All participants filled in the questionnaire and all except eight participated in the clinical study. Hence, unlike those seeking orthodontic treatment in North America [1], the socioeconomic status and/or parents' health behaviour did not seem to influence participation.

Similarly to Norwegians [20], young Estonian adults paid attention to anterior occlusal traits. In line with Danes [21], those who were satisfied with their teeth had less crowding and overjet than those who were dissatisfied.

With regard to overjet, Estonian young adults' threshold for dissatisfaction was in line with that of Finnish orthodontists, who regard an overjet of up to 5 mm as acceptable [22]. However, the threshold value is less than the generally applied threshold in selection for orthodontic treatment [23,24].

Although one in four of the participating young adults had had or was currently undergoing orthodontic treatment, one in three of the untreated participants had a need for treatment as per ICON. This share is higher than that of untreated 15–16-year-olds in Finland (18%) [15]. Exclusion of those with previous or current orthodontic treatment, and possible tooth extractions may have reduced the treatment complexity because fewer than 10% of the cases were categorized as difficult or very difficult. The corresponding percentages among 7–10-year-old Estonian children were 26 and 51, respectively [13]. Orthodontic or other dental treatment during the development of occlusion seems to have resulted in a reduction of deviated occlusal traits. This residual treatment need may also be a consequence of lack of patient compliance, or lack of available treatment options or manpower. Moreover, a borderline treatment need might also have been rather difficult to diagnose [25].

More than two in three young adults were satisfied or very satisfied with their dental health and the arrangement of their teeth. Although half of the participants responded that they did not need orthodontic treatment, one in three indicated several reasons for why they would desire it.

Table 3. Satisfaction with dental health, alignment of own teeth and self-perceived orthodontic treatment need compared with an ICON assessment of Estonian 17–21-year-olds ($n = 390$).

	Treatment need		Total	
	ICON ≤43 (*N*)	ICON >43 (*N*)	*N*	%
Satisfaction with dental health				
Very satisfied	32	7	39	10
Satisfied	156	81	237	61
I do not care	14	9	23	6
Dissatisfied	42	38	80	21
Not satisfied at all	2	1	3	0
I don't know	4	3	7	2
No answer	0	1	1	0
Total	250	140	390	100.0
	Treatment need		Total	
	ICON ≤43 (*N*)	ICON >43 (*N*)	*N*	%
Satisfaction with alignment and appearance of teeth				
Very satisfied	44	10	54	14
Satisfied	151	74	225	58
Dissatisfied	40	45	85	22
Unhappy	2	2	4	1
I don't know	12	9	21	5
No answer	1	0	1	0
Total	250	140	390	100.0
	Treatment need		Total	
	ICON ≤43 (*N*)	ICON >43 (*N*)	*N*	%
Desire for orthodontic treatment				
Definitely not	20	5	25	6
No, I don't think so	138	52	190	49
Yes, I think so	75	71	146	38
Yes, definitely	16	11	27	7
No answer	1	1	2	0
Total	250	140	390	100.0

In line with other studies [15,26], the most frequent reason for orthodontic treatment was an improvement in dental appearance. The distribution of answers regarding dental appearance, ease of cleaning and lower risk for caries were in line with the responses of Finnish 15–16-year-olds; however, improvement of jaw function was not highlighted among Estonians. Further, in contrast to the Finnish results [15], there was no gender difference in Estonia.

Future studies should focus on several aspects raised in this study. The share of orthodontically treated young adults seemed to be in line with international levels, but more research is needed to evaluate the allocation of orthodontic care with consideration for various occlusal deviations. Furthermore, although objective and subjective perceptions of orthodontic treatment need were rather consistent, there were inconsistencies with regard to desire for treatment.

Conclusions

The present results indicate that

- The most prevalent occlusal traits were Class I sagittal relationship in canines and molars, crowding, the end-to-end sagittal relationship in canines, and increased overbite and overjet. More than one in three had an antero-posteriorly asymmetrical canine and molar sagittal relationship.
- According to ICON, one in three untreated Estonian 17–21-year-olds had orthodontic treatment need. In most cases, the treatment complexity was moderate or mild.
- A statistically significant positive association was found between participants' desire to get their teeth straightened and orthodontic treatment need to be assessed using ICON. Both female and male participants' main expectation was an improvement in dental appearance.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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PUBLICATION
IV

Mandibular movements in children with deciduous and mixed dentition and in young adults with permanent dentition-the association between movements and occlusal traits

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Original article

Mandibular movements in children with deciduous and mixed dentition and in young adults with permanent dentition—the association between movements and occlusal traits

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Summary

Background: Cross-sectional studies of mandibular movements provide data on developmental trends of dentition and support planning of public health services.

Objective: The aim of this study was to measure mandibular movement capacities in children with deciduous and mixed dentition and in young adults with permanent dentition. The influence of age and gender on mandibular movements and the association between mandibular movements and occlusal traits were analysed.

Method: The sample consisted of 1172 Estonians: group 1: children with deciduous dentition; group 2: children with mixed dentition; and group 3: young adults with permanent dentition. Maximum opening, mandibular laterotrusion, and protrusion were registered.

Results: Age was correlated with mandibular movements. Young adults had statistically significantly larger mandibular movements as compared to children with deciduous and mixed dentition, and children with mixed dentition had larger mandibular movements as compared to children with deciduous dentition. Young adult males had larger mandibular movements than females of the same age. Associations were found between mandibular movement capacities and some occlusal traits. Mandibular movement capacities were smaller in children with crossbite and open bite as compared with children without corresponding occlusal traits. Mandibular movement capacities were larger in children with deep bite and increased overjet as compared with those without corresponding occlusal traits.

Conclusion: Mandibular movement capacities are age and gender dependent. Maximum mouth opening, mandibular laterotrusion, and protrusion are related, and mandibular movement and some occlusal traits are associated.

Introduction

Health of the masticatory organ is a good indicator of the overall well-being of an individual (1, 2). In addition to treatment of biofilm diseases, oral care ought to achieve an optimal functional balance between temporomandibular joint (TMJ) and occlusion. Integration of occlusal development with facial structures and the head and neck region is complex, especially during childhood and mixed dentition stage (3). During normal growth, the mandibular condyle has been found to undergo significant changes in size and shape as part of occlusal development and maturation of the masticatory organ (4). Therefore, it is understandable that also a range of mandibular movements change during growth as indicated in the literature

(5–7). In an optimal situation, TMJ adapts, even in adulthood, to various occlusal traits because of the adaptive nature of condylar secondary cartilage (8, 9).

Various factors may affect the stomatognathic system (10) and reduce the movement capacity of the mandible. In TMJ, internal derangement or, in active TMJ, inflammation-reduced mandibular movements are common findings (11). Limited mandibular movements may be associated with pain, discomfort, and disruption of daily activities—ability to eat and phonate, maintain oral hygiene, and perform dental treatment, if needed (1).

Free and relaxed mandibular movements are an essential part of a healthy masticatory organ (12), and the examination of mandibular movement capacity is an essential part of a thorough clinical examination of the masticatory organ. To the best of our knowledge, the literature on mandibular movement capacities in relation to occlusal traits is lacking.

The aims of this study were to:

1. measure mandibular movement values in children with deciduous and mixed dentition and in young adults with permanent dentition;
2. analyse the influence of age and gender on mandibular movements; and
3. analyse the association between mandibular movements and occlusal traits.

The working hypotheses of the study were that:

1. mandibular movements increase with age and are larger in boys than in girls and
2. associations can be found between mandibular movements and occlusal traits in children with deciduous and mixed dentition and in young adults with permanent dentition.

Subjects and methods

This study complements earlier studies on the prevalence of occlusal traits in Estonian children and young adults (13–15) with measurements of mandibular movements. A 95.0 per cent confidence interval around an estimate (±2.5 per cent of the estimate) was specified for sample size calculation. In the sampling, a stratified cluster design was implemented (16). The list of all kindergartens and elementary/high schools from three biggest cities located in different geographic areas of Estonia was acquired from the local government (*n* = 61 elementary/high schools and *n* = 191 kindergartens). Randomly selected school/kindergarten was contacted and asked to participate in the study. Of the contacted schools and kindergartens, 20.0 per cent declined to attend mainly because they did not have a doctor's office. The recruitment took place in 11 kindergartens and 4 elementary/high schools, and the number of invited subjects was 1512. From invited subjects, 340 were excluded for different reasons: 1. previous or current orthodontic treatment (*n* = 169), 2. parents did not agree to let their child participate in the clinical study (*n* = 64), 3. children were too afraid to participate in the clinical study (*n* = 62), 4. children were not in kindergarten on the examination day (*n* = 41), and 5. three children had cleft lip and palate and one had hemifacial microsomia. Final sample consisted of 1172 Estonians in three groups: group 1: 4–5-year-old children with deciduous dentition (*n* = 390, 190 girls, 200 boys, mean age 4.7 ± 0.9 years); group 2: 7–10-year-old children with mixed dentition (*n* = 392, 198 girls, 194 boys, mean age 9.0 ± 0.8 years); group 3: 17–21-year-old young adults with permanent dentition (*n* = 390; 219 females, 171 males, mean age 18.5 ± 0.9 years). The sampling procedure is illustrated in Figure 1.

All participants and their parents/guardians signed an informed consent form, indicating that their participation in the study was voluntary. The study protocol was approved by the Ethics Review Committee on Human Research of the University of Tartu (Protocol No. 186T-24).

Registration of the occlusal traits was based on international standards (17–19). Detailed criteria of registration have been published previously (13). Flush terminal plane denotes the condition when the distal surface of the mandibular and maxillary second deciduous molar end in the same vertical plane and mesial/distal terminal plane when the distal surface of the mandibular second deciduous molar is mesial/distal to the corresponding surface in the maxillary second deciduous molar.

For the present study, maximum mouth opening (MMO), lateral movement of the mandible to right and left (LMMr and LMMl), and protrusive movement of the mandible (PMM) were registered on the basis of international standards and recommendations (20). MMO, LMMr, and LMMl were measurable in all the participants. PMM was measurable in all of groups 2 and 3 and in 106 children (27.2 per cent) in group 1.

All the clinical examinations for all the participants were performed by the same orthodontist. The examination of the 4–5-year-old children was carried out in the kindergarten's medical office and the examination of the 7–10-year-old children and the 17–21-year-old young adults was carried out at the school's dental office

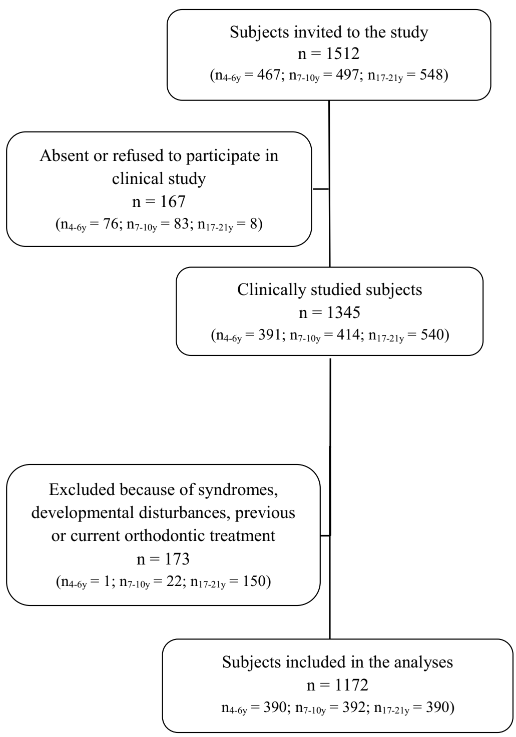

Figure 1. Selection of the final study sample.

using a dental mirror, probe, pencil (0.3 mm), and millimetre ruler (Dentaurum 042-751 Münchner Modell).

Registration criteria

The registration of mandibular movement was started with centric occlusion. To obtain centric occlusion, the orthodontist gently verified that the mandible was relaxed, and then the participant was asked to bite together lightly.

To obtain MMO, participants were asked to open their mouth slowly, as wide as possible, without specifying 'end feel'. The distance between the incisal edge (close to midline) of the upper and lower central incisors was measured. Overbite was considered in recording MMO.

The midline between maxillary central incisors was marked with a pencil on the labial surface of the mandibular incisor in centric occlusion. The participant was asked to move the mandible slowly to maximum excursion to the right (LMMr) and to maximum excursion to the left (LMMl). The distance between pencil marks was recorded.

The subject was asked to move the mandible slowly to maximum protrusion (PMM). The distance between the incisal edges of the upper and lower central incisors was recorded parallel to the occlusal plane. Overjet was considered in recording PMM. The maximum opening and the lateral and protrusive movements of the mandible were repeated, and the mean of two measurements was used in the study.

Reliability and statistical analyses

Before the study, 22 4–5-year-old, 22 7–10-year-old children, and 22 17–21-year-old young adults were examined clinically and re-examined after a 1-week interval by the orthodontist who performed all the clinical examinations of the study. The reliability was good ($r > 0.95$). A detailed description of the reliability of clinical examinations of occlusal traits has been presented previously (13–15).

The data were checked for normality, and appropriate analysis methods were selected. Reference range for MMO, PMM, and LMM was calculated. Reference range contains the central 95.0 per cent of the population. For age-group differences, analysis of variance with the Bonferroni *post hoc* test was applied. In addition, the odds for higher values of MMO, LMMr, LMMl, and PMM in boys and girls were evaluated with logistic regression. Differences in LMMr and LMMl were calculated with a paired *t*-test. To examine the correlation between MMO, LMMr, LMMl, and PMM, Pearson's correlation was used. Differences in MMO, LMMr, LMMl, and PMM between genders and occlusal traits (mesial, distal, and flush terminal plane; molar and canine Class I, II, and III and end to end; open (overjet <0 mm) and deep bite (overbite ≥3.5 mm); crossbite and scissor bite) were calculated with an independent *t*-test and Welch *t*-test (in case of unequal sample size). *P* values of less than 0.05 were considered statistically significant. The analyses were carried out with IBM SPSS Statistics (version 20.0; IBM Armonk, New York, USA).

Results

Mandibular movements

Deciduous dentition (group 1)

The mean ± standard deviation (SD) of MMO was 43.6 ± 4.6 mm, range 32.0, and mode 45.0 mm (6.7 per cent). The mean of LMMr and LMMl was 9.5 ± 2.6 mm and 9.4 ± 2.7 mm, respectively. There was no statistically significant difference between LMMr and LMMl ($P = 0.348$). The range of LMMr and LMMl was 15.0 and mode 10.0 mm (29.2 and 26.4 per cent, respectively). The mean of PMM was 2.6 ± 1.9 mm, range 8.5, and mode 1.5 mm (4.9 per cent).

Mixed dentition (group 2)

The mean ± SD of MMO was 49.2 ± 5.0 mm, range 31.0, and mode 46.0 mm (6.6 per cent). The mean of LMMr and LMMl was 11.3 ± 2.3 mm and 10.8 ± 2.2 mm, respectively; the difference was statistically significant ($P < 0.001$). The range of LMMr and LMMl was 15.0 and 17.0, respectively, and mode 12.0 mm (24.0 and 24.7 per cent, respectively). The mean of PMM was 7.5 ± 2.3 mm, range 13.0, and mode 9.0 mm (15.6 per cent).

Permanent dentition (group 3)

The mean ± SD of MMO was 54.3 ± 7.5 mm, range 46.0, and mode 49.0 mm (3.6 per cent). The mean of LMMr and LMMl was 11.6 ± 2.5 mm and 11.6 ± 2.4 mm, respectively. There was no statistically significant difference between LMMr and LMMl ($P = 0.842$). The range was 18.0 and 17.0 respectively, and mode 12.0 mm (23.1 and 24.1 per cent, respectively). The mean of PMM was 8.6 ± 2.5 mm, range 15.5, and mode 9.0 mm (11.0 per cent).

The distribution of the findings of mandibular movements in deciduous, mixed, and permanent dentition are presented in Figure 2. Age was moderately correlated with MMO ($r = 0.610$, $P < 0.001$), LMMr ($r = 0.355$, $P < 0.001$), LMMl ($r = 0.369$, $P < 0.001$), and PMM ($r = 0.442$, $P < 0.001$). The correlations of MMO, LMMr, LMMl, and PMM are presented in Figure 3.

MMO was statistically significantly different between groups 1 and 2 (5.4 mm), between groups 1 and 3 (10.7 mm), and between groups 2 and 3 (5.3 mm; $P < 0.001$). Lateral movement to the right was different between groups 1 and 2 (1.7 mm) and between groups 1 and 3 (2.0 mm; $P < 0.001$), but no statistically significant difference between groups 2 and 3 ($P = 0.278$) was present. Lateral movement to the left was statistically significantly different between groups 1 and 2 (1.4 mm), between groups 1 and 3 (2.1 mm), and between groups 2 and 3 (0.7 mm; $P < 0.001$). Protrusion movement was statistically significantly different between groups 1 and 2 (4.9 mm), groups 1 and 3 (5.9 mm), and groups 2 and 3 (1.1 mm; $P < 0.001$; Figure 4). Young adult males' permanent dentition had statistically

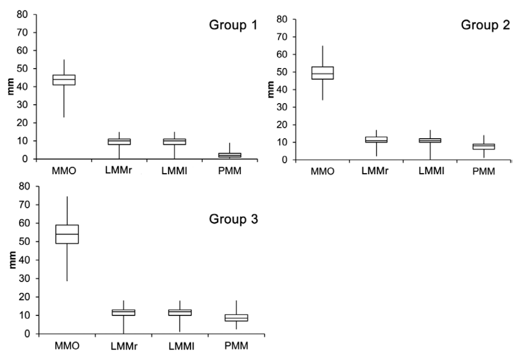

Figure 2. Box plots of maximum mouth opening (MMO), lateral (LMMr and LMMl) and protrusive (PMM) movements in deciduous (group 1, $n = 372$), mixed (group 2, $n = 392$), and permanent dentition (group 3, $n = 390$).

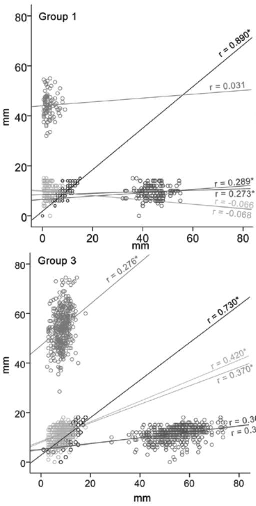

Figure 3. Correlations of maximum mouth opening (MMO), lateral (LMMr and LMMl) and protrusive (PMM) movements in deciduous (group 1, n = 372), mixed (group 2, n = 392), and permanent dentition (group 3, n = 390). *Statistically significant correlations between mandibular movements (P < 0.05). Black—LMMr versus LMMl, red—MMO versus PMM, blue—MMO versus LMMl, green—MMO versus LMMr, grey—PMM versus LMMr, yellow—PMM versus LMMl.

significantly larger mandibular movements in MMO, LMMr, LMMl, and PMM as compared with females and, in PMM, the difference existed already in mixed dentition (Table 1).

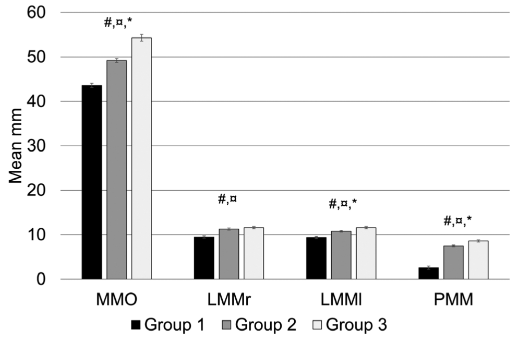

Figure 4. Maximum mouth opening (MMO), lateral (LMMr and LMMl) and protrusive (PMM) movements in deciduous (group 1, n = 372), mixed (group 2, n = 392), and permanent dentition (group 3, n = 390). Mean and 95.0 per cent confidence intervals. #Statistically significant difference between groups 1 and 2 (P < 0.05); ¤Statistically significant difference between groups 1 and 3 (P < 0.05); *Statistically significant difference between groups 2 and 3 (P < 0.05).

Association between mandibular movements and occlusal traits (Table 2)

Deciduous dentition (group 1)

Maximum opening was smaller in children with lateral crossbite, open bite, and anterior crossbite as compared with children without corresponding occlusal traits (P = 0.002, P < 0.001, and P < 0.001, respectively). Laterotrusions (LMMr and LMMl) were smaller in children with lateral crossbite (P = 0.021 and P = 0.003 in LMMr and LMMl, respectively) and in children with anterior

Table 1. Gender differences of mandibular movements in deciduous (group 1, n = 372), mixed (group 2, n = 390), and permanent dentition (group 3, n = 390). The mean ± standard deviation (SD) and odds ratios (ORs) with 95.0 per cent confidence interval (CI) and reference range for maximum mouth opening (MMO), lateral (LMMr and LMMl), and protrusive (PMM) movements in boys and girls. Ref: females.

	Group 1		Group 2		Group 3	
	Girls	Boys	Girls	Boys	Girls	Boys
MMO (*n*)	190	200	198	193	214	157
Mean ± SD (mm)	43.0 ± 4.6	43.6 ± 4.6	49.3 ± 4.7	49.0 ± 5.2	52.1 ± 6.5	57.3 ± 7.8*
95% CI	43.0–44.3	43.0–44.3	48.6–49.9	48.3–49.8	51.2–53.0	56.1–58.6
OR (95% CI)	1.00 (0.96–1.04)		0.99 (0.95–1.03)		1.11 (1.07–1.15)*	
Reference range	33–54		38–60		38–71	
LMMr (*n*)	190	199	198	194	214	158
Mean ± SD (mm)	9.5 ± 2.7	9.5 ± 2.6	11.2 ± 2.3	11.3 ± 2.4	11.3 ± 2.3	11.9 ± 2.7*
95% CI	9.1–9.9	9.1–9.8	10.9–11.5	11.0–11.7	11.0–11.6	11.5–12.4
OR (95% CI)	1.00 (0.92–1.08)		1.03 (0.94–1.12)		1.11 (1.02–1.21)*	
Reference range	4–15		6–16		6–17	
LMMl (*n*)	190	200	198	194	214	158
Mean ± SD (mm)	9.4 ± 2.7	9.4 ± 2.6	10.8 ± 2.0	10.8 ± 2.3	11.2 ± 2.4	12.1 ± 2.4*
95% CI	9.0–9.8	9.0–9.8	10.5–11.1	10.5–11.2	10.8–11.5	11.7–12.5
OR (95% CI)	1.00 (0.93–1.08)		1.01 (0.92–1.10)		1.19 (1.08–1.31)*	
Reference range	3–15		6–16		6–17	
PMM (*n*)	50	56	197	192	214	158
Mean ± SD (mm)	2.7 ± 1.8	2.6 ± 2.0	7.1 ± 2.3	7.9 ± 2.2*	8.2 ± 2.3	9.0 ± 2.7*
95% CI	2.2–3.2	2.0–3.1	6.8–7.5	7.6–8.2	7.9–8.5	8.6–9.5
OR (95% CI)	0.97 (0.79–1.18)		1.15 (1.06–1.26)*		1.15 (1.05–1.25)*	
Reference range	0–7		2–13		3–14	

*Statistically significant difference between gender (P < 0.05).

Table 2. Occlusal traits and the mean ± standard deviation (SD) for maximum mouth opening (MMO), lateral (LMMr and LMMl), and protrusive (PMM) movements in deciduous (n = 372), mixed (n = 390), and permanent dentition (n = 390). OJ: overjet, OB: overbite.

	MMO (mm)		LMMr (mm)		LMMl (mm)		PMM (mm)	
	Yes	No	Yes	No	Yes	No	Yes	No
Group 1								
Mesial terminal plane (n = 131)			10.1 ± 2.0 (n = 130, 33.4%)	9.2 ± 2.8* (n = 259, 66.6%)				
Flush terminal plane (n = 167)			9.1 ± 2.5 (n = 167, 42.9%)	9.7 ± 2.7* (n = 222, 57.1%)				
Distal terminal plane (n = 187)	43.1 ± 4.8 (n = 187, 47.9%)	44.1 ± 4.4* (n = 203, 52.1%)						
Canine Class III (n = 15)	38.6 ± 7.4 (n = 15, 3.8%)	43.9 ± 4.4* (n = 375, 96.1%)						
Canine end to end (n = 164)	44.4 ± 4.3 (n = 164, 42.1%)	43.1 ± 4.8* (n = 226, 57.9%)						
Posterior crossbite (n = 68)	42.1 ± 5.2 (n = 68, 17.4%)	44.0 ± 4.4* (n = 322, 82.6%)			8.5 ± 3.6 (n = 68, 17.4%)	9.6 ± 2.4* (n = 322, 82.6%)	1.6 ± 1.5 (n = 16, 15.1%)	2.8 ± 1.9* (n = 90, 84.9%)
Anterior crossbite (n = 33)	40.0 ± 6.8 (n = 33, 8.5%)	44.0 ± 4.2* (n = 357, 91.5%)	7.6 ± 4.1 (n = 33, 8.5%)	9.6 ± 2.4* (n = 356, 91.3%)	7.6 ± 4.2 (n = 33, 8.5%)	9.6 ± 2.4* (n = 357, 91.5%)		
Negative overbite (n = 12)	38.0 ± 6.5 (n = 12, 3.1%)	43.8 ± 4.4* (n = 378, 96.9%)						
Overjet ≥ 3.5 mm (n = 61)	45.3 ± 4.2 (n = 61, 15.6%)	43.3 ± 4.6* (n = 329, 84.4%)					5.2 ± 1.7 (n = 16, 15.1%)	2.2 ± 1.6* (n = 90, 84.9%)
Overbite ≥ 3.5 mm (n = 151)	45.1 ± 4.1 (n = 151, 38.7%)	42.8 ± 4.7* (n = 239, 61.3%)	10.1 ± 2.1 (n = 151, 38.7%)	9.1 ± 2.8* (n = 238, 61.0%)	9.9 ± 2.1 (n = 151, 38.7%)	9.1 ± 2.9* (n = 238, 61.0%)		
Crossbite or open bite (n = 123)	42.6 ± 5.0 (n = 123, 31.5%)	44.1 ± 4.4* (n = 267, 68.5%)			8.9 ± 3.t3 (n = 123, 31.5%)	9.6 ± 2.2* (n = 267, 68.5%)		
OJ ≥ 3.5 or OB ≥ 3.5 (n = 188)	44.9 ± 4.0 (n = 188, 48.2%)	41.5 ± 4.8* (n = 202, 51.8%)	9.0 ± 2.3 (n = 188, 48.3%)	9.1 ± 2.8* (n = 201, 51.7%)	9.7 ± 2.3 (n = 188. 48.2%)	9.1 ± 2.9* (n = 202, 51.8%)	3.5 ± 2.1 (n = 47, 44.3%)	1.9 ± 1.5* (n = 59, 55.7%)
Group 2								
Molar Class I (n = 225)							7.1 ± 2.4 (n = 225, 57.8%)	8.0 ± 2.2* (n = 164, 42.2%)
Molar Class II (n = 86)							8.6 ± 2.2 (n = 85, 21.9%)	7.2 ± 2.3* (n = 304, 78.1%)
Canine Class I (n = 289)							7.2 ± 2.3 (n = 286, 73.5%)	8.4 ± 2.1 (n = 103, 26.5%)
Canine Class II (n = 14)							9.4 ± 1.4 (n = 14, 3.6%)	7.4 ± 2.3* (n = 375, 96.4%)
Canine Class III (n = 9)							5.8 ± 1.6 (n = 9, 2.3%)	7.5 ± 2.3* (n = 382, 97.7%)
Canine end to end (n = 163)							7.8 ± 2.4 (n = 162, 41.6%)	7.3 ± 2.3* (n = 227, 58.4%)
Open bite (n = 84)	48.1 ± 4.6 (n = 82, 20.9%)	49.4 ± 5.0* (n = 308, 78.6%)						

Table 2. Continued

	MMO (mm)		LMMr (mm)		LMMl (mm)		PMM (mm)	
	Yes	No	Yes	No	Yes	No	Yes	No
Anterior crossbite (n = 9)	39.3 ± 4.9 (n = 9, 2.3%)	45.1 ± 5.5* (n = 382, 97.4%)						
Negative overbite (n = 6)	44.3 ± 2.6 (n = 6, 1.5%)	49.2 ± 4.9* (n = 385, 98.2%)						
Overjet ≥ 3.5 mm (n = 147)							8.7 ± 2.1 (n = 144, 37.0%)	6.8 ± 2.2* (n = 245, 63.0%)
Overbite ≥ 3.5 mm (n = 203)	49.8 ± 5.0 (n = 203, 51.8%)	48.5 ± 4.8* (n = 188, 48.0%)					7.8 ± 2.3* (n = 202, 51.5%)	7.2 ± 2.3* (n = 187, 47.7%)
Scissor bite (n = 6)	56.5 ± 6.8 (n = 6, 1.5%)	49.0 ± 4.8* (n = 385, 98.2%)						
Crossbite or open bite (n = 123)	48.4 ± 4.7 (n = 122, 31.1%)	49.5 ± 5.0 (n = 269, 68.6%)						
OJ ≥ 3.5 or OB ≥ 3.5 (n = 243)	49.6 ± 5.0 (n = 242, 61.9%)	48.4 ± 4.7* (n = 149, 38.1%)					7.9 ± 2.3 (n = 240, 61.7%)	6.9 ± 2.2* (n = 149, 38.3%)
Group 3								
Molar Class II (n = 92)	52.8 ± 7.6 (n = 88, 23.7%)	54.8 ± 7.4* (n = 283, 76.3%)					9.1 ± 2.6 (n = 88, 23.7%)	8.4 ± 2.4* (n = 284, 76.3%)
Molar Class III (n = 51)							7.5 ± 2.7 (n = 50, 13.4%)	8.7 ± 2.4* (n = 322, 86.6%)
Molar end to end (n = 114)					12.0 ± 2.3 (n = 110, 40.3%)	11.4 ± 2.5 (n = 262, 59.7%)		
Canine Class III (n = 26)							6.9 ± 2.8 (n = 26, 7.0%)	8.7 ± 2.4* (n = 346, 93.0%)
Canine end to end (n = 183)			11.9 ± 2.3 (n = 176, 47.3%)	11.3 ± 2.6* (n = 196, 52.7%)	11.8 ± 2.4 (n = 176, 47.3%)	11.3 ± 2.5* (n = 196, 52.7%)		
Overjet ≥ 3.5 mm (n = 183)							9.5 ± 2.2 (n = 176, 47.3%)	7.7 ± 2.4* (n = 196, 52.7%)
Anterior crossbite (n = 24)							6.8 ± 2.4 (n = 24, 6.2%)	8.7 ± 2.4* (n = 348. 89.2%)
Scissor bite (n = 41)							9.6 ± 2.7 (n = 40, 10.3%)	8.5 ± 2.4* (n = 332, 85.1%)
OJ ≥ 3.5 or OB ≥ 3.5 (n = 263)							8.9 ± 2.4 (n = 250, 67.2%)	7.9 ± 2.4* (n = 122, 32.8%)

*Statistically significant difference between children with certain occlusal trait as compared with those without corresponding occlusal trait (P < 0.05).

crossbite as compared with those without corresponding occlusal traits ($P < 0.001$ and $P < 0.001$, respectively). Maximum opening was larger in children with deep bite and increased overjet as compared with those without corresponding occlusal traits ($P < 0.001$ and $P = 0.002$, respectively).

Mixed dentition (group 2)

Maximum opening was larger in children with deep bite ($P < 0.001$) as compared with those without a corresponding occlusal trait and smaller in children with open bite or crossbite ($P = 0.016$, $P < 0.002$, respectively) as compared with those without a corresponding occlusal trait.

Permanent dentition (group 3)

Mandibular protrusion was larger in young adults with increased overjet or overbite ($P < 0.001$, $P < 0.002$, respectively) as compared with those without a corresponding occlusal trait.

Discussion

The present cross-sectional, population-based study provides values for mandibular movements in 4–5-year-old children with deciduous dentition, 7–10-year-old children with mixed dentition, and 17–21-year-old young adults with permanent dentition. In addition, the study points out associations between mandibular movement capacities and occlusal traits during those stages in dental development.

The difficulty of taking exact measurements in young children has been pointed out previously (6). Our experience confirmed that patience and time are needed when examining young children. Still, despite talking to the children, visualizing, and practicing, protrusive mandibular movement could not be registered in all 4–5-year-old children.

The mean for mandibular movement capacities in 7–10-year-old Estonian children was found to be similar as in previous studies of 10–13-year olds (5) and 8–10-year olds (21). The mean for mandibular movement capacities in 17–21-year olds was in line with that of 14–17-year olds (5). However, in our study, the means for maximum mouth opening and lateral movements in 4–5-year olds were clearly larger than in a Brazilian sample of 4.6 years, where those with TMJ dysfunction had been excluded from analyses (6), and clearly larger in 7–10-year olds than in an Argentinian sample of 6–12 years (22).

Statistically significant difference was found between right and left lateral mandibular movement capacities in mixed dentition, but not in deciduous or permanent dentition. Earlier studies have also found the difference (5, 23), while others have not reported it (24). Theoretically, right and left lateral movements should not differ. Further studies are needed to find out reasons behind the difference. The finding may be clinically important if the difference exists constantly.

To the best of our knowledge, this study is the first to examine correlations between various mandibular movements. In all age groups, the relationship between maximum mouth opening and lateral and protrusive movements was clear. Future studies should assess to what extent the finding of moderate/strong correlation applies/exists throughout the aging process/through development (i.e. childhood/adolescent development).

In line with other studies (5–7), age and dental stage are associated with mandibular movement capacities. Maximum mouth opening was 5.3-mm larger in 17–21-year olds with permanent dentition as compared to 7–11-year olds with mixed dentition and 10.7-mm larger as compared to 4–5-year olds with deciduous dentition. Lateral and protrusive mandibular movements were also larger in young adults than in children with mixed and deciduous dentition.

It seems that the mean of maximum mouth opening capacity increases to the level of 54.3 mm by age 17–21 and remains at that level until about age 30–40, after which it seems to decrease. Two studies report 43.0 mm for mean maximum mouth opening at age 61–70 (25, 26). The value is the same as in early childhood at the age of 4–5 years (43.0 mm) in the present study.

Hirsch *et al.* (5) reported a gender difference in maximum mouth opening in young adults with permanent dentition. Likewise, in the present study, young adult boys had 1.1 times higher odds of having larger maximum mouth opening values compared to girls of the same age. Young adult boys had also larger lateral and protrusive values compared to girls. For protrusion, the gender difference was present already in mixed dentition; boys had higher values compared to girls of the same age. Gender differences in mandibular movement capacities were not present in 4–5-year-old children, which is in line with Argentinian 3–11-year olds (6). In the present study, the gender difference appeared at the age of 17–21 years and has been shown to persist until age 61–70 (25).

Age, developmental stage of dentition, and gender should be taken into account in evaluating mandibular movement capacities and in defining possible restricted mandibular movement capacity. Proposed reference ranges are based on our cross-sectional study. To develop frames of reference or normative values, like threshold values, for any biological measurement, would require future studies conducting in much larger material than ours and in several ethnical populations.

The exclusion of subjects with any history of conditions that may decrease or increase mandibular movement capacity would reduce the number of participants with restricted or hypermobile mandibular movement capacities. In this study, this exclusion was not done.

Mandibular movement capacity is related to the anatomic form of mandibular condyle, glenoid fossa, and is dependent on the relationship between occlusion and condylar position (4). Based on the present study, various occlusal traits seem to be associated with changes in mandibular movement capacity. A limitation of the present study is that, in the sub-group analyses, sample sizes have been unbalanced, which must be kept in mind when interpreting the findings.

Individuals with certain occlusal traits had a different maximum mouth opening and lateral and protrusive movement capacities compared with the sample mean of these movements—in spite of the fact that the sample mean also included individuals with occlusal traits associated with mandibular movement capacities. This finding is very important clinically.

Children with crossbite and open bite have shown to have lower muscular activation and specific chewing pattern (27–29). Based on the findings of the present study, mandibular movement capacity is smaller in children with crossbite and open bite as compared with children without corresponding occlusal traits.

Mandibular movement capacity may be a sign of a functional disturbance in dentofacial development. The finding highlights the necessity to evaluate mandibular movement capacities carefully as part of each clinical examination.

Conclusions and hypothesis

1. The present study confirmed earlier findings and supports our hypothesis that mandibular movement capacities increase with age and that young adult males have larger mandibular movements as compared with females of the same age.
2. This study adds novel information and confirms our second hypothesis. There is a relationship between maximum mouth opening and lateral and protrusive movements of the mandible. Associations exist between mandibular movement capacities and crossbite, open bite, deep bite, and increased overjet. Mandibular movement capacities are smaller in children with crossbite and open bite as compared with children without corresponding occlusal traits. Mandibular movement capacities are larger in children with deep bite and increased overjet as compared with those without corresponding occlusal traits.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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