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# The risk for infraposition of dental implants and ankylosed teeth in the anterior maxilla related to craniofacial growth, a systematic review

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## ABSTRACT

**Background:** The aim of the study was to evaluate a potential association between individuals with different craniofacial types or other exposures, and the risk of infraposition due to continued growth/eruption of adjacent teeth in the anterior maxilla.

**Materials and methods:** This is a systematic review in which primary studies as well as other systematic reviews are scrutinised. A search of PubMed (Medline), Scopus, Web of science and Health technology assessment (HTA) organisations and a complementary handsearch was carried out. Selected studies were read in full-text by several reviewers. The quality of the included primary studies was assessed using a protocol for assessment of risk of bias in exposure studies.

**Results:** The literature search resulted in 3,296 publications. Title and abstract screening yielded 25, whereof one systematic review, potential publications allocated for full-text inspection. The quality assessment resulted in a total of seven studies with a low/moderate risk of bias and four studies with a high risk of bias.

**Conclusion:** In conclusion, a long-term risk for infraposition of dental implants, or ankylosed teeth, among natural teeth can be observed in some cases. The predisposing factors are still not fully understood since the current scientific evidence is very limited.

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## KEYWORDS

Dental implants; ankylosed teeth; infraposition; continued development; systematic review

## Introduction

Missing teeth in the anterior region of the maxilla in young individuals could be due to congenital factors or trauma. External trauma and root fractures were the most common reasons for tooth loss (49%) whilst congenital factors accounted for 15% of the single-tooth spaces [1]. Missing teeth can lead to functional as well as aesthetic challenges. Young patients with lost or congenitally missing teeth are often treated early in life, and the aesthetic long-term outcome may be of particular concern. It is important to initiate treatment-planning early in order to have all treatment options available. Treatment alternatives in the dentition of a young individual might be temporary prosthodontic rehabilitation, orthodontic treatment, preservation of the deciduous teeth and autotransplantation. Dental implant treatment is considered to be an alternative with a high survival and success rate as shown in several studies [2–7]. However, some negative observations have been reported for long-term aesthetic outcome, e.g. infraposition of the implant-supported crown, marginal bone loss, (fistula), discoloured buccal gingiva (when using titanium metal coloured implants), gingival retraction/recession and periimplantitis [8–11].

In still growing children and young adults, dental implants as well as trauma injured ankylosed teeth might, due to the lack of functioning periodontal ligament, become progressively infrapositioned over time in relation to the surrounding teeth [12–20]. This implies that the crown appears shorter than the adjacent teeth which to a varying degree affects the aesthetic appearance.

For this reason, it has been suggested that an appropriate time-point for implant placement is at the age when skeletal growth is considered to be completed [21,22]. According to a study by Taranger and Hägg [24] the pubertal growth spurt began on average at the age of 10.0 years in girls, and 12.1 years in boys and ceased at 14.8 years and 17.1 years, respectively. Peak height velocity, in both sexes, occurred two years after the onset of the growth spurt (12.0 years and 14.1 years). Growth terminated at 17.5 years in girls and 19.2 years in boys. In addition to differences between the sexes there is also a large variation between individuals [23]. In a study by Pancherz *et al.* investigation of the facial skeleton and dental changes over time were performed using cephalometric measurements. On their study sample, they presented results where both the maxillary and mandibular bases grew anteriorly even after puberty [24]. Behrents investigated growth in the aging craniofacial skeleton and found

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changes even after the age of 40 [25]. Even when growth is finished, continuous eruption or continued positional changes of the adjacent teeth, especially in the maxillary incisor region, may result in infraposition of the implant-supported crown, and potentially even more so in the case of a deviant facial type [26–29]. This could possibly be explained by the disparity between patients with different vertical craniofacial growth pattern (horizontal and vertical growth of the face). Assuming that continued eruption is a compensatory mechanism for facial growth, it seems reasonable to conclude that eruption follows the general pattern of craniofacial growth [30–32]. In a previous study, Klinge *et al.* investigated the association between craniofacial height and alveolar bone dimensions. They found that patients with large vertical craniofacial height had a significantly higher alveolar bone both in the maxilla and in the mandible compared to the patients with low craniofacial features [33]. These results indicate that in a vertical growing individual there might be a greater risk of developing infraposition due to the growth of the alveolar bone height.

It seems that infraposition is a complex issue where craniofacial type could be one relevant factor (a decisive piece of the puzzle). If it were possible to pinpoint a recommendation for when to insert dental implants based on craniofacial type this would no doubt be of great value to the adolescents/young adults, both from a psychological, functional and aesthetic point of view. The aim of this study is to evaluate a potential association between individuals of different craniofacial types as well as other exposures (e.g. sex and age) and risk of infraposition (of crowns on ankylosed teeth or dental implants) due to continued growth/eruption of adjacent teeth in the anterior maxilla.

## Materials and methods

### Objective

The aim of this study was to investigate risk factors for infraposition during dental implant treatment or in cases of ankylosed teeth. The protocol was registered at PROSPERO International prospective register of systematic reviews: CRD42019136675.

### Eligibility criteria for studies

Eligibility criteria for studies were as follows: a predefined study population, age and sex registered for the patients, and registration of infraposition over time. PICO (Patients, Intervention/Exposure, Control group, Outcome), as well as inclusion and exclusion criteria for the eligible studies are summarised in Table 1.

### Literature search

A literature search was performed (3<sup>rd</sup> June 2019) by two of the authors (AK and ANA) and an scientific information specialist at Malmö university library. No time limitations from

**Table 1.** PICO and inclusion/exclusion criteria.

<b>P</b>	Adolescents, young adults and adults with ankylosed teeth or who had been treated with dental implant
<b>I</b>	Age, sex, facial morphology, diseases, or other potential studied risk factors
<b>C</b>	Other levels of the same exposures
<b>O</b>	Infraposition Other measures of continued growth
<b>Systematic reviews</b>	<b>Inclusion criteria</b> Systematic review Systematic meta-analysis English abstract <b>Exclusion criteria</b> Non-systematic review Guidelines Letter Position paper Consensus statements
<b>Primary studies</b>	<b>Inclusion criteria</b> English abstract Longitudinal studies <b>Exclusion criteria</b> Animal studies In vitro studies Lack of follow-up

inception up to 03 June 2019. The search only included studies in English. The search strategies are presented in Table 2.

### Search strategies

The following databases were searched: Pubmed (Medline), Scopus and Web of science. The search was performed without any filters. The search terms used for the databases are summarised and presented in Table 2. Search terms used were e.g. continued eruption, infraposition, infraocclusion, growth and development, jaw, maxilla, alveolar bone, dental implant and tooth ankylosis. The following Health technology assessment (HTA) organisations were searched regarding dental implant infraposition or infraocclusion until 3<sup>rd</sup> June 2019: National Institute for Health and Care Excellence (NICE), <http://www.nice.org.uk/>; CADTH, <http://www.cadth.ca/>; CRD database, <http://www.crd.york.ac.uk/CRDWeb/>; Kunnskapssenteret, <http://www.kunnskapssenteret.no/home?language=english>, and ASERNIP-S <http://www.surgeons.org/for-health-professionals/audits-and-surgical-research/asernips/publications/>. The reference lists of all the eligible studies were handsearched for potential complementary studies.

### Study selection

The Rayyan software program (Qatar Computing Research Institute (Data Analytics)) was used to manage the references and remove duplicates. The retrieved list of publications was subjected to a crude exclusion of irrelevant publications based on title. In case of uncertainty, a study remained included until the next selection step, which consisted of an assessment of abstracts. The abstracts were read by four reviewers independently in pairs of two (AK and ST; ANA and JB). Selected studies were read in full-text by four reviewers respectively (AK, ANA, ST, NW). Any disagreement during the screening process was resolved by discussion in the project group.

**Table 2.** Search strategy.

Database	Search strategy
Medline (PubMed)	'continued eruption' OR infraposition OR infraocclusion OR growth OR development OR growth[Mesh] OR growth and development[Mesh] AND Jaw OR Jaw[Mesh] OR maxillary OR maxilla OR maxilla[Mesh] OR mandibular OR mandible OR mandible[Mesh] OR 'alveolar bone' OR 'alveolar process' OR alveolar process[Mesh] OR 'dental arch' OR dental arch[Mesh] AND
Scopus	'dental Implant*' OR dental implants[Mesh] OR dental Implantation[Mesh] OR 'tooth ankylos*' OR tooth ankylosis[Mesh] ( ( TITLE-ABS-KEY ( 'continued eruption' ) ) OR ( TITLE-ABS-KEY ( infraposition ) ) OR ( TITLE-ABS-KEY ( infraocclusion ) ) OR ( TITLE-ABS-KEY ( growth ) ) OR ( TITLE-ABS-KEY ( development ) ) ) AND ( ( TITLE-ABS-KEY ( jaw ) ) OR ( TITLE-ABS-KEY ( maxillary ) ) OR ( TITLE-ABS-KEY ( mandibular ) ) OR ( TITLE-ABS-KEY ( 'alveolar bone' ) ) OR ( TITLE-ABS-KEY ( 'dental arch' ) ) ) AND ( ( TITLE-ABS-KEY ( 'dental implant*' ) ) OR ( TITLE-ABS-KEY ( 'tooth ankylos*' ) ) ) )
Web of science	#1 'continued eruption' #2 infraposition #3 infraocclusion #4 growth #5 development #6 #1 OR #2 OR #3 OR #4 OR #5 #7 jaw #8 maxillary #9 maxilla #10 mandibular #11 mandible #12 'alveolar bone' #13 'alveolar process' #14 'dental arch' #15 #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 #16 'dental implant*' #17 'tooth ankylos*' #18 #16 OR 17 #19 #6 OR #15 OR #18

Duplicates, non-clinical studies, case reports, animal studies, guidelines, letters, position paper studies on patients with systemic diseases or syndromes, studies on implant-supported overdentures or tooth-and-implant restorations, studies on surgical or short-term outcomes, and studies with nonrelevant outcomes were excluded.

### Assessment of risk of bias

#### Systematic reviews

The quality of the included systematic review was assessed using AMSTAR (<https://amstar.ca/docs/AMSTAR-2.pdf>).

#### Primary studies

The risk of bias of the included primary studies was assessed using a protocol for assessment of risk of bias in exposure studies [34]. The assessment comprised selection bias, exposure bias, detection bias, attrition bias, and reporting bias.

### Data extraction

#### Systematic reviews

No systematic reviews were eligible for data extraction, the one systemic review identified was excluded due to employing a different methodological approach than the present review. Data extraction would have been the following: objectives, main results, authors' estimated certainty of evidence, and knowledge gaps according to authors.

#### Primary studies

Data was extracted from the primary studies regarding population (number of included patients), study period (length of follow-up), age, sex, craniofacial type, type of outcome (infraposition measured or other relevant outcomes).

#### Certainty of the evidence

The certainty of the evidence in the studies was rated according to GRADE (GRADing quality of Evidence and strength of recommendations). GRADE has four steps of evidence grading; high, moderate, low, and very low [35].

### Results

#### Literature search and study selection

The literature search resulted in 3,296 publications. Search strategy, presented for each database, is shown in Table 2. The search of HTA organisations did not yield any further studies. Flowcharts of the screening process for the studies are shown in Figure 1.

Title and abstract screening yielded 25 potential publications gathered for full-text inspection and inclusion for further analysis. Primary studies that were regarded as nonrelevant to the current systematic review were excluded at this stage and the reason for exclusion was recorded (Table 3) [27,28,36–46].

### Assessment of risk of bias and data extraction

#### Systematic reviews

One systematic review was eligible for quality assessment [47]. However, the systematic review was excluded due to it

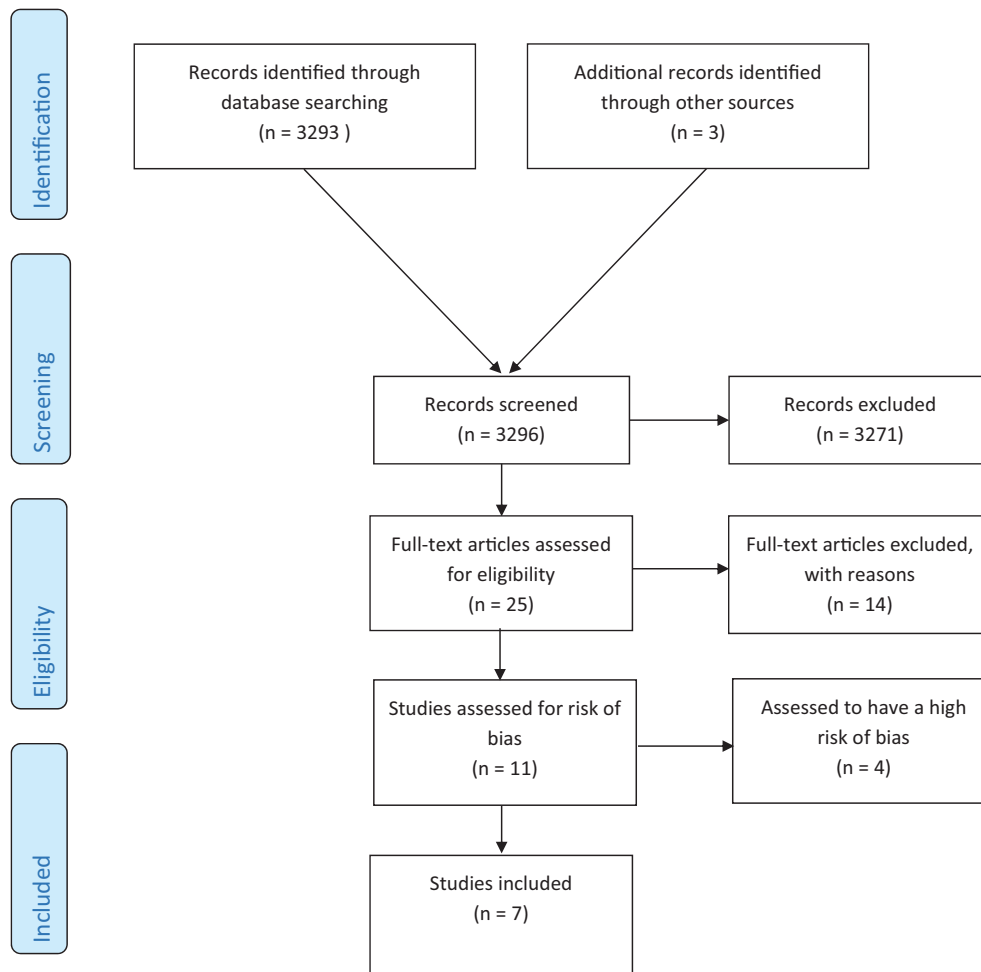


Figure 1. PRISMA 2009 flow diagram.<sup>1</sup>

Table 3. Studies (in full text) excluded due to lack of relevance.

Author	Year	Reason for exclusion
Bohner et al.	2019	Does not address the present research question
Carmichael et al.	2008	Neither primary nor SR study
Chrancanovic et al.	2019	Does not address the present research question
Kamatham et al.	2019	Does not address the present research question
Lin et al.	2013	Does not address the present research question
Malmgren B et al.	1984	Does not address the present research question
Mohadeb et al.	2016	Does not address the present research question
Op Heij	2006	Neither primary nor SR study
Op Heij	2003	Neither primary nor SR study
Papageorgiou	2018	SR with differences in methodological approach compared to the present review
Ruan	2018	Does not address the present research question
Thilander	1999	Duplicate/same subjects as another study
Vilhjamsjon	2013	Does not address the present research question
Jemt et al.	2006	Does not address the present research question

employing a different methodological approach than the present review (Table 3).

### Primary studies

The quality assessment resulted in seven studies with a low/moderate risk of bias and four studies with a high risk of bias. Selection bias, exposure bias, detection bias, attrition bias, reporting bias, for the eleven studies are presented in

Figure 2(a) (low or moderate risk of bias), and Figure 2(b) (high risk of bias) [19,48–50].

Type of exposure, study population characteristics and outcome for studies classified as being of low or moderate risk of bias are shown in Table 4. Due to diversity in study design and outcome, statistical analysis was not applicable.

In a study by Aarts et al. [51], the potential difference in craniofacial growth cessation between short, average and long face subjects as an implication for the timing of implant

(a)

Study	Selection bias	Exposure bias	Detection bias	Attrition bias	Reporting bias	Summary
Aarts et al. 2015	Medium risk	Low risk	Medium risk	Low risk	Low risk	Low/moderate risk of bias
Bernard et al. 2004	Low risk	Low risk	Medium risk	Not applicable	Low risk	Low/moderate risk of bias
Brahem et al. 2017	Low risk	Low risk	Medium risk	Low risk	Low risk	Low/moderate risk of bias
Fudalej et al. 2007	Low risk	Low risk	Medium risk	Not applicable	Medium risk	Low/moderate risk of bias
Kawanami et al. 1999	Medium risk	Low risk	Low risk	Medium risk	Low risk	Low/moderate risk of bias
Schwartz-Arad et al. 2013	Low risk	Low risk	Medium risk	Medium risk	Low risk	Low/moderate risk of bias
Thilander et al. 1994	Low risk	Medium risk	Low risk	Low risk	Low risk	Low/moderate risk of bias
Low risk      Medium risk      High risk						

(b)

Study	Selection bias	Exposure bias	Detection bias	Attrition bias	Reporting bias	Summary
Andersson et al. 2013	Medium risk	Medium risk	Medium risk	High risk	High risk	High risk of bias
Jemt et al. 2007	Low risk	Medium risk	High risk	High risk	Low risk	High risk of bias
Cocchetto et al. 2019	Medium risk	High risk	High risk	High risk	Medium risk	High risk of bias
Malmgren et al. 2002	Medium risk	Medium risk	Medium risk	High risk	High risk	High risk of bias
Low risk      Medium risk      High risk						

Figure 2. (a) Risk of bias in studies included in the SR conclusion. (b) Risk of bias in studies not included in the conclusion.

placement was investigated. Measurements of anatomical landmarks on cephalogram were performed at different time-points. Orthodontic treatment was completed between 14–18 years of age (males) and 13–17 years of age (females). Cessation of facial growth was evaluated by e.g. if (Is-Pal) change was less than 1 mm between two measurements (2, 5, 10 years follow up), and if so, considered stable. 169 patients were included. No statistical difference between facial type group were found.

Bernard et al. [52], evaluated the effects of the tooth-eruption process of teeth adjacent to implant-borne restorations in adult patients compared to patients in their late adolescence. Follow-up time was between 1 year 8 months and 9 years 1 month (mean 4.2 years). No difference was found in the amount of vertical displacement of the adjacent teeth between male and female patients, nor between different positions of the implant. The study included 28 subjects, divided in two equal age groups (young group (15.5–21 years),  $n=14$ , mature group (40–55 years),  $n=14$ ). Twelve out of

the 28 patients had two implants inserted (right and left side) and for these patients the mean value was used for statistics which might have affected the result.

The study sample of Brahem et al. [53], measured standing height and implants were inserted after documented stabilisation of growth height. Fifty-seven patients (37 with pre-implant orthodontic treatment and 20 without) were included. Ages of the study sample were between 18 and 61 years (mean  $29.7 \pm SD 10$  years). Time of follow up were from baseline examination approximately five weeks after crown placement, to final follow-up examination of minimum five years ( $>5$  years. Mean 7 years  $\pm 1$  year). Infra-position was evaluated according to a score. Twenty-eight patients received one single crown implant, 26 patients received two single crown implants and three patients received three single crown implants each. No relationship was found between maximal tooth displacement of incisors, pre-implant orthodontic treatment and orthodontic retention, sex, and age at the end of treatment.

Table 4. Characteristics and quality assessment of included primary studies with low or moderate risk of bias.

Author Year Country	Population	Study period	Exposures	Outcome	Results	Risk of bias Comments
Aarts et al. 2015 Netherlands	169 patients that completed orthodontic treatment as adolescents	10 years after completed orthodontic treatment (2, 5, 10 years)	Age: 14–18 years of age (males) and 13–17 years of age (females) at time of orthodontic treatment completion. Sex: (m/f) 88/81 Facial types: Short (SN/MP $\leq 28^\circ$ ) $n=48$ Average (SN/MP $31.5^\circ-34.5^\circ$ ) $n=77$ Long (SN/MP $\geq 38^\circ$ ) $n=44$	Cessation of facial growth, 10 years (Is-Pal) – less than 1 mm change between two measurements (2, 5, 10 years)	Proportion stable year 10 Short: 95.2% Average: 100% Long: 90.5% Males: 87.5% Females: 96.3%	Low/moderate risk of bias No adjustment for confounding factors Historic cohort
Bernard et al. 2004 Switzerland	28 patients with missing anterior teeth, insertion of single implants in the anterior maxilla. Young group $n=14$ Mature group $n=14$ 40 implants	1 year 8 months to 9 years 1 month (mean 4.2 years)	Age: Young group 15.5–21 years (mean age at surgery 18.4 years) and mature group 40–55 years (mean age at surgery 43.6 years) Sex: (m/f) 10/18	Continued growth of teeth adjacent to implant	Infraosition: 0.1–1.65 mm (young group) and 0.12–1.86 mm (mature group) No diff. between sexes	Low/moderate risk of bias Short follow-up time for some individuals >1 year
Braham et al. 2017 Denmark	57 patients (37 with pre-implant orthodontic treatment and 20 without) 89 single crown implants in the maxilla	>5 years. Mean 7 years $\pm$ 1 year	Age: 18–61 years (29.7 $\pm$ SD 10 years) Sex: (m/f) 20/37	Infraosition (modified Jemt et al. [50]). Score: A: < 0.25mm B: 0.25–0.49mm C: 0.5–0.74mm D: 0.74–0.99mm E: $\geq$ 1mm (horizontal or vertical change)	Vertical movement: > 0.25mm 87% of the central incisors in the test group and 70% in the control group. > 0.5mm 38% in the test group and 35% in the control group 4/57 had >1mm vertical or horizontal displacement	Low/moderate risk of bias
Fudalej et al. 2007 Poland and U. S	301 patients orthodontically treated	T1: pretreatment T2: end of treatment T3: $\geq$ 10 years post-treatment From the age of 12 every 3 <sup>rd</sup> year until 30 years of age and then 10-year intervals til 50 years of age 1–21 years (mean 4.2 years). Study cast every 6 month	Age: 12–50 years Sex: (m/f) 142/159	Cephalometric X-ray at T2 and T3 Eruption of maxillary incisors	Incisors Males: mean 2mm Females: 2.7mm Most changes occurred between the ages of 12–15	Low/moderate risk of bias Not taking into account facial shape and growth pattern is a limitation
Kawanami et al. 1999 Japan, Denmark	52 patients with ankylosed maxillary central or lateral incisors	1–21 years (mean 4.2 years). Study cast every 6 month	Age: 6–48 years at time of injury Sex: (m/f) 33/19	Infraosition in mm/year	Infraosition Males <16 years of age: mean 0.42 mm/year Males: 16–19 years of age: 0.14 mm/year Males: > 19 years of age: 0.07 mm/year Females <14 years of age: mean 0.58 mm/year Females >14 years of age: mean 0.58 mm/year	Low/moderate risk of bias
Schwartz-Arad et al. 2013 Israel	35 patients $\leq$ 30 years or >30 years at time of implant placement (22/13)	>3 years Mean 7.5 years $\pm$ 4.5 years	Age: 29.2 $\pm$ 10.9 years Sex: (m/f) 14/21	Submersion rate of dental implant crown in % of crown of adjacent natural tooth (incisal edge to buccal CEJ) / follow-up time	Mean submersion rate 1.02% in the $\leq$ 30 years group and 0.27% in the >30 years group	Low/moderate risk of bias

(continued)

Table 4. Continued.

Author Year Country	Population	Study period	Exposures	Outcome	Results	Risk of bias Comments
Thilander et al. 1994 Sweden (Follow-up in 2001)	11 patients 17 fixtures in the anterior maxilla (Originally 15 patients and 27 implants including both maxilla and mandible)	>3 years (in the study from 2,00,110-year follow-up)	Age: 13 years 2 month-19 years 4 month. (Mean age at implant placement 15.1 years), Sex: (m/f) 6/5 Increase height: mean 5.3 cm, range 0–18 cm	Infraposition in mm (study cast, X-ray)	Mean/SD Increase body height <3 cm: 0.14/ 0.17 mm ≥3 cm: 0.81/ 0.34 mm Males: 0.63/ 0.53 mm Females: 0.36/ 0.27 mm Age < 15 years: 0.64/0.45 mm Age ≥ 15 years: 0.34/0.40 mm	Low/moderate risk of bias Information on study design from 1994 and follow-up from 2001

In a study by Fudalej et al. [54], the purpose was to evaluate the amount of craniofacial growth and the amount of eruption of the central incisors after puberty. Follow up time was from end of orthodontic treatment to ten years postretention. Observational age intervals were every 3rd year from the age of 12 until 30 years of age and then ten year intervals til 50 years of age. The anterior facial height (AFH) in men increased by a total of 9.4 mm (SE = 0.7) during the observation period from the ages 12 to 50 years. Over half of the increase took place before the age of 15. In females, the total change in AFH over the entire observation period was 4.3 mm (SE = 0.4). About 40% of the growth in AFH occurred before the age of 15. For both sexes, about 60% to 70% of the increase in AFH occurred in the lower anterior face height. Most of the changes in both facial height and in amount of eruption of central incisors occurred at an early age but changes could be observed throughout the whole observation period.

In the study by Kawanami et al. [55], the purpose was to register the extent of infraposition after replantation of avulsed teeth and to relate this event to the age and sex of the patient.

The study samples were between 6 and 48 years at time of the dental injury. Follow-up time was 1–21 years (mean 4.2 years). Study casts were made every 6 month and a yearly increase in infraposition was calculated each year of age. Vertical distances from the reference plane to the incisal edges were measured by one examiner using a Jocal digital calliper (C.E. Johansson, Eskilstuna, Sweden). Almost all cases demonstrated increasing infraposition over time. Rapid increase in infraposition was identified in patients where ankylosis occurred during childhood and adolescence. Slowly increasing infraposition was also found in cases where ankylosis occurred after the age of 20–30 years. The yearly increase in infraposition for males varied between 0.19 and 0.62 mm before the age of 16 and between 0.11 and 0.18 mm from 16 to 19 years of age. In females the yearly increase in infraposition ranged between 0.08 and 1.00 mm when ankylosis occurred before the age of 14 years.

Schwartz-Arad and Bichacho [56], investigated the submersion rate of single dental implants in the central maxillary incisor region compared with the adjacent natural tooth and association with age. The mean age at implant placement was  $29.2 \pm 10.9$  years. A clinical and radiographic follow-up of at least three years with a mean follow-up time of  $7.5 \pm 4.5$  years were performed. When investigating implant submersion rate according to age, there were statistically significant differences between the two groups (35 patients divided in two age groups  $\leq 30$  years or  $> 30$  years at time of implant placement).

In the studies by Thilander et al. [29,57], dental implants in adolescents were investigated. The study population were 13 years 2 month to 19 years 4 month, with a mean age at implant placement of 15.1 years. The follow-up time was  $> 3$  years in the study published 1994 and 10-years follow-up in the study published 2001 on the same subjects. In three patients, four crowns in the maxilla were replaced and excluded. The crowns were changed for aesthetic reasons e.g. colour,



**Table 5.** Summary of findings for effects of exposures on continued growth/eruption of teeth in the alveolar bone of the anterior maxilla.

Exposure	References	Outcome	Number of subjects (studies)	Results	Certainty of the evidence (GRADE)	Reason for grading down
<b>Age</b>	Bernard et al. [52] Brahem et al. [53] Fudalej et al. [54] Kawanami et al. [55] Schwartz-Arad and Bichacho [56] Thilander et al. [29,57]	Continued growth/eruption of teeth	485 (6)	Six studies analysed the impact of age. The results showed that continued eruption was present at all the ages included, some studies were able to show that the rate of growth was significantly higher in younger subjects, i.e. those aged 15 or younger.	Very low ⊕○○○	Risk of bias –2 <sup>a</sup> Inconsistency –1 <sup>b</sup>
<b>Facial type</b>	Aarts et al. [51]	Continued growth/eruption of teeth	169 (1)	One study evaluated the impact of facial type. There were no significant differences in growth between facial types.	Very low ⊕○○○	Risk of bias –2 <sup>c</sup> Imprecision –1 <sup>d</sup>
<b>Sex</b>	Aarts et al. [51] Bernard et al. [52] Brahema et al. [53] Fudalej et al. [54] Kawanami et al. [55] Schwartz-Arad and Bichacho [56] Thilander et al. [57]	Continued growth/eruption of teeth	654 (7)	Seven studies looked at whether or not the subject's sex influenced growth. Only one study showed significant differences with more growth in female subjects.	Very low ⊕○○○	Risk of bias –2 <sup>e</sup> Inconsistency –1 <sup>f</sup>
<b>Tooth position</b>	Bernard et al. [52]	Continued growth/eruption of teeth	28 (1)	One study evaluated the impact of tooth position in the anterior maxilla. There were no significant differences in growth between tooth positions.	Very low ⊕○○○	Risk of bias –2 <sup>g</sup> Imprecision –1 <sup>h</sup>

⊕○○○ Level of certainty of evidence according to GRADE.

<sup>a</sup>Weaknesses in study design and statistics.

<sup>b</sup>Inconsistency in the timings, outcome measures, and results between studies.

<sup>c</sup>Weaknesses in study design and statistics. One study (not duplicated).

<sup>d</sup>Few events, not statistically significant.

<sup>e</sup>Weaknesses in study design and statistics.

<sup>f</sup>Inconsistency in the timings and outcome measures.

<sup>g</sup>Weaknesses in study design and statistics. One study (not duplicated).

<sup>h</sup>Few events, not statistically significant.

crown anatomy or because of fracture due to trauma. This drop out may influence the results since the study population was relatively small (11 patients and 17 fixtures in the anterior maxilla). In four of the patients, including a total of six implants in the upper incisal region, the position of the implant-crowns was vertically changed to an unacceptable position from a clinical point of view. This also involved the gingiva leading to an apical shift of the gingival margin of the implant-crown.

## Summary of findings

Summary of findings for effects of exposures on continued growth/eruption of teeth in the alveolar bone of the anterior maxilla is presented in Table 5.

There is very low-quality evidence for continued growth in the alveolar bone of the anterior maxilla even after skeletal growth is considered finished, with a higher rate in young patients.

## Discussion

The aim of this systematic review was to evaluate the potential relationship between several exposures and continued growth in the anterior maxilla, resulting in infraposition of ankylosed teeth or dental implants in relation to the adjacent teeth. We identified seven

primary studies, with different aims, at low or moderate risk of bias. The studies' differing aims and heterogeneity between the seven studies precluded meta-analysis.

Hence, we were unable to clearly pinpoint the predisposing (risk) factors for infraposition of dental implants in the anterior maxilla. There is a lack of well-designed studies with multivariate analysis including investigation of craniofacial type, age, and sex. A previous systematic review [47], on a similar topic was identified, but unlike the current paper, this review included studies at either high risk, or unclear risk of bias in their meta-analyses.

The description 'unclear risk of bias' when a lack of information about material and methods precludes assessment of scientific quality is per se acceptable. However, including such studies in the meta-analysis as comparable to studies at either low or moderate risk of bias seems speculative and could be misleading to an inexperienced reader.

To summarise, meticulous and stringent quality assessment of primary studies and reviews are important before drawing conclusions, especially when the conclusions are relevant to clinical practice.

Our findings highlight the fact that there is a need of new studies with a thorough study protocol, including a proper number of subjects, and a well-defined and calibrated investigation technique, to improve the scientific knowledge.

## Conclusion

It was not possible to establish evidence for a certain time-point being more suited for insertion of dental implants in order to avoid infraposition with time due to continued growth/development/eruption. The influence of the craniofacial height in association with infraposition needs to be further investigated.

## Note

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No potential conflict of interest was reported by the author(s).

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