

## Systematic review

# Dental implants in growing patients: a systematic review

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## Abstract

The aim of this systematic review (for which we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines) was to provide an overview of the protocols and clinical outcomes of dental implants placed in growing jaws. We searched the MEDLINE/PubMed, Embase, Scopus, and Science Direct databases in October and November, 2017. A total of 3492 studies were identified, and all the studies reporting the outcomes of dental implants placed during the growth phase were included in the study.

After duplicates had been removed, 2133 studies were screened based on their titles and abstracts, and 162 were selected for reading. Finally, 28 studies were included in the review. Overall, 493 dental implants were placed in 147 patients aged from 3–18 years old with follow-up being from 1–20 years. The most common disorders seen that were associated with missing teeth were ectodermal dysplasia and dental trauma. The main complications reported were the infraocclusion positioning of dental implants in the maxillary arch and the rotation of dental implants in the mandibular arch. Dental implants were indicated for the anterior regions of the maxilla and mandible in patients over 10 years old, and placement of maxillary implants in a more coronal position was recommended. Consultations and adjustments to prostheses were required until growth had ceased. In growing jaws, dental implants require positional modifications, and they should be considered only under special circumstances.

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*Keywords:* dental implants; children; growth

## Introduction

The absence of permanent teeth as a result of dental trauma or congenital aplasia is common in children and adolescents,<sup>1</sup> and can lead to aesthetic limitations that impair social acceptability, such as functional difficulties related to eating and speech. Prosthodontic approaches to oral rehabilitation are therefore usually required for growing patients.

Plans to replace missing teeth are based on each patient's systemic condition, developmental phase, number of missing teeth, and the anatomy of the hard and soft tissue. Although conservative prosthodontic rehabilitation is the treatment of choice until growth has ceased, conventional approaches do

not usually satisfy the needs of a growing patient, particularly if bone is deficient.<sup>2,3</sup>

Dental implants are reliable options for patients during the growth phase. However, the efficacy of such treatment is uncertain because there are few clinical studies that have evaluated the functional and aesthetic outcomes with long-term follow-up.<sup>3,4</sup> To date, opinions about this treatment have diverged. On the one hand, implant-supported prostheses are well-accepted by young patients,<sup>5</sup> and they may benefit from the blood supply and uncomplicated healing provided by growing bone.<sup>6</sup> Several reports have shown the aesthetic and functional success of this treatment during long-term follow-up of up to six years.<sup>7–9</sup> On the other hand, the placement of dental implants is susceptible to complications related to growth patterns, because dental implants act as ankylosed teeth, and they do not follow the movement of the surrounding structures. Changes in the position of the

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implant during growth are therefore common. These complications are not usually correctable, and they may inhibit the success of restorative procedures, so the patient's age and the maxillary growth pattern must be considered when planning treatment.<sup>10–12</sup>

Although several authors have discussed the implications of placing implants in growing patients, there is no consensus about the ideal age, positioning, or number of implants that are required for safe treatment.<sup>6,13</sup> Clinicians must be aware of the limitations and possible complications related to placing implants in these patients.

This systematic review was therefore designed to answer the following questions: “What complications are related to the placement of dental implants in growing jaws?” and “Is there a specific protocol that provides a favourable outcome of treatment?” The purpose was to provide an overview of published protocols and clinical outcomes of dental implants placed in growing jaws.

## Material and methods

### Registration of protocol

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses Guidelines.<sup>14</sup> It was registered with the International Prospective Register of Systematic Reviews under protocol number CRD42018081114.<sup>15</sup>

### Eligibility criteria

The inclusion criteria were: studies that described the treatment and follow-up of dental implants installed in growing jaws. Because of the lack of clinical trials on the subject, no restrictions were applied to the design of a study. Conversely, reviews, books, and abstracts, and studies that did not present the outcomes of dental implants in patients younger than 18 years old, and studies written in languages other than English and German, were excluded.

Table 1

Main search strategy.

#### PICOS:

P = (young) OR (adolescents) OR (children) OR (oligodontia) OR (anodontia) OR (hypodontia)

I = (dental implant) OR (single-tooth implant) OR (dental implants[MeSH Terms])

C = -

O = (success) OR (survival) OR (failure) OR (outcome) OR follow-up)

S = -

#### Search (PubMed-Medline):

(Young) OR (adolescents) OR (children) OR (oligodontia) OR (anodontia) OR (hypodontia) AND (dental implant) OR (single-tooth implant) OR (dental implants[MeSH Terms]) AND (success) OR (survival) OR (failure) OR (outcome) OR (follow-up)

### Sources of information

The search was made in October and November of 2017, and was updated in November 2018. The following electronic databases were assessed: MEDLINE/PubMed, Scopus, Embase and Science Direct. The main search strategy was developed based on the PICOS model (patients, interventions, comparisons, outcomes and types of study) (Table 1), which was applied to the MEDLINE/PubMed database. The search strategy was also individualised for each of the other databases (Appendix A) (supplemental data). Additionally, we manually searched the reference lists, Google Scholar, and Research Gate to complement the electronic search. The Rayyan software program (Qatar Computing Research Institute (Data Analytics) was used to manage the references and remove the duplicated studies.<sup>16</sup>

### Selection of studies

The studies were selected by two reviewers (LB and MH) independently, and if there was any disagreement, a third reviewer (SJ) was consulted. First, the articles were screened for full-text reading based on a review of the titles and abstracts. Only those papers that were relevant based on reading of the full text were included in the analysis.

### Data collection

The first reviewer (LB) extracted the relevant data from the eligible articles and organised them into tables, which were crosschecked by the second reviewer (MH). The extracted data consisted of information about the study design, treatment protocols, surgical interventions, restorative procedures, and follow-up assessments. If any information was missing, the authors were consulted by email. If the authors did not respond the paper was excluded from analysis.

### Within-study risk of bias

The observational studies were assessed using the Methodological Index for Non-randomised Studies (MINORS),<sup>17</sup> and the case reports and case series were evaluated using the Joanna Briggs Institute checklist.<sup>18</sup> The MINORS instrument includes seven items about the quality of the methods used in non-comparative studies, which were scored as follows: 0 = not reported, 1 = reported inadequately, and 2 = reported adequately. The Joanna Briggs instrument comprises a critical checklist for appraisal of case reports, with answers of yes, no, or unclear (Appendix B) (Supplemental data).

## Results

### Selection of studies

A total of 3492 studies were selected from the electronic and manual searches. After duplicates had been removed, 2133

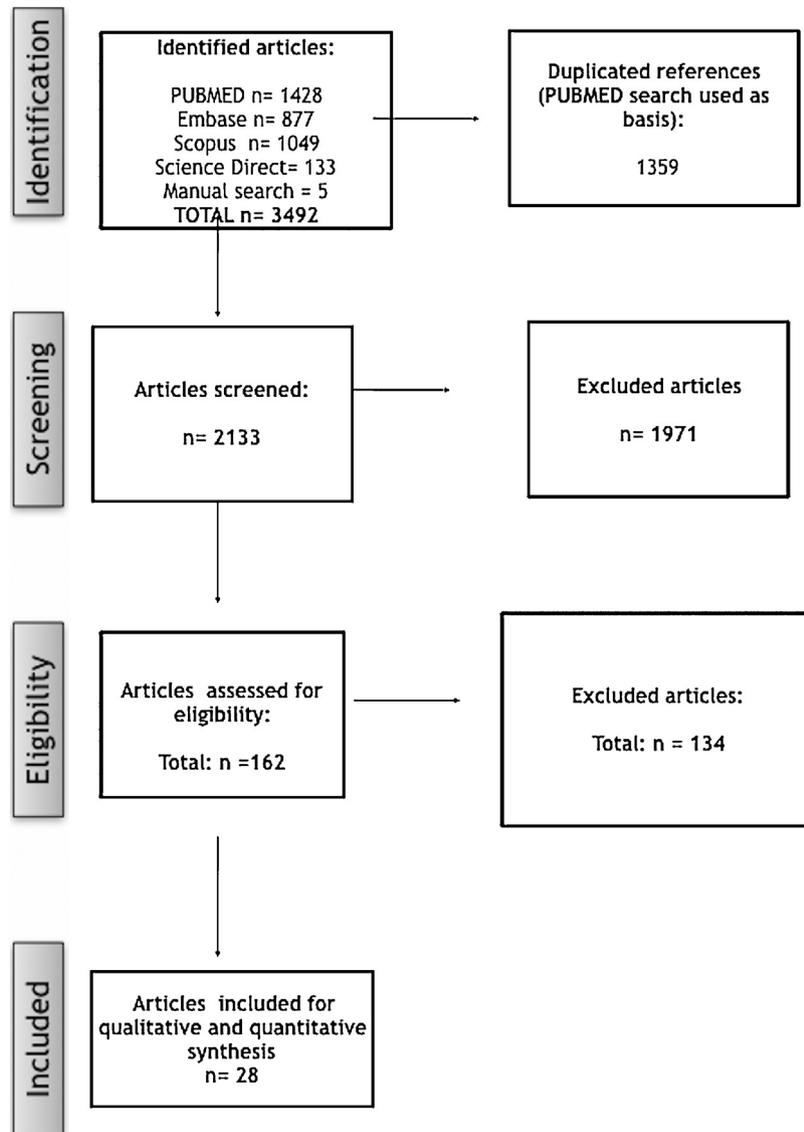


Fig. 1. Algorithm showing the collection and analysis of data.

studies were screened based on the titles and abstracts. Of these, 162 were considered for reading of the full text (Fig. 1). Finally, 28 studies were included in the analysis. The reasons for exclusion are described in Appendix C (supplemental data).

#### *Design of studies and characteristics of patients*

We included four retrospective studies, four prospective studies, 19 case reports, and three case series that evaluated patients between 3 and 17 years old. Overall, 493 dental implants were placed in 147 patients. The most common medical condition was the absence of one or more teeth because of a congenital disorder,<sup>1,3,5,7–9,12,19–31</sup> although dental trauma was also reported<sup>1,10,19,28,32,33</sup> (Tables 2 and 3). Additional information about the main characteristics of the studies included is given in Appendix D (Supplemental data).

#### *Position of the implants and restorative procedures*

Details of the surgical and restorative procedures are shown in Tables 4 and 5. Seventeen studies evaluated dental implants in the maxilla,<sup>3,4,7,11,12,19,20,23,24,28,30,32–34</sup> and 19 dental implants in the mandible.<sup>1,3–5,8,9,12,21–31,34,35</sup> With regard to the osseointegration period, intervals of three to 10 months were reported between the placement of the dental implant and the restorative procedure, with the exception of two studies in which the protocol consisted of the early loading of restored dental implants.<sup>4,7</sup>

Oral rehabilitations were with single crowns<sup>1,3,4,7,10,11,19,20,23,32,33,35</sup> and removable prostheses<sup>9,21,22,24,25,27,29–31</sup> or those supported by fixed implants.<sup>1,5,12,24,30,34</sup> Adjustments were made to dental prostheses during the follow-up period in six of the studies.<sup>9,20,24,31,33</sup> Several strategies were used to make sure

Table 2  
Study design and patient features of cohort studies.

Author, year, and reference	Study design	No. of patients	No. of implants	Age (years)	Medical history	Intraoral condition	Follow-up period (years)	Complications
Bergendal 2008 <sup>28</sup>	Retrospective	26	47	5–15	Ectodermal dysplasia, Dental trauma, non-syndromic agenesia	Tooth agenesia, anodontia	20	23.4% of implant loss
Bernard 2004 <sup>11</sup>	Retrospective	6	10	15–18	Trauma, congenital aplasia	Missing anterior teeth	1–9	Infra-occlusion
Brahim 2005 <sup>26</sup>	Prospective	35	255	7–17	Ectodermal dysplasia	Minimum of 16 missing permanent teeth	0–3	8.7% of implant loss
Heuberer, 2012 <sup>8</sup>	Retrospective	3	8	6–10	Ectodermal dysplasia	Oligodontia	1–5	No complications reported
Heuberer 2015 <sup>3</sup>	Retrospective	18	71	6–16	Congenital absence	Oligodontia	11	11% of implant loss
Lambert 2017 <sup>4</sup>	Prospective	12	30	13.8–16.7	–	One or more missing teeth	1–7.4y	3.4% of implant loss, crown failure, crown loosening, restoration color change
Thilander 2001 <sup>1</sup>	Prospective	18	47	13–17	Congenital absence or dental trauma	Missing teeth	10y	Infra-occlusion

PPD = Probing pocket depth; mPI = modified plaque index; PI = Plaque index; BOP = Bleeding on probing.

Table 3  
Features of patients described in case reports.

Author, year, and reference	No. of patients	No. of implants	Age (years)	Medical history	Intraoral condition	Follow-up period (years)	Complications related to the implants
Alcan 2006 <sup>35</sup>	1	4	4	Ectodermal dysplasia	Anodontia, Oligodontia	6	No complications reported
Becktor 2001 <sup>34</sup>	1	4 (maxilla), 5 (mandible)	8	Ectodermal dysplasia	Oligodontia	12	Implant inclination
Bergendal 2015 <sup>31</sup>	1	2	6	Ectodermal dysplasia	Anodontia of the mandible	24	Exposed threads of one of the implants
Filius 2014 <sup>29</sup>	4	8	6–13	Ectodermal dysplasia	Oligodontia or anodontia	3.2–8.4	Implant inclination
Giannetti 2010 <sup>32</sup>	1	1	10	Dental trauma	Missing maxillary central incisor	2	No complications reported
Guckes 1997 <sup>21</sup>	1	6	3	Ectodermal dysplasia	Oligodontia	5	No complications reported
Huang 2014 <sup>30</sup>	1	6	13	Ectodermal dysplasia	Absence of permanent dentition	20	Maxillary implants failed
Kearns 1999 <sup>24</sup>	6	41	5–17	Ectodermal dysplasia	Totally and partially edentulous	6–11	Infra-occlusion
Kilic 2017 <sup>9</sup>	1	2	6	Ectodermal dysplasia	Oligodontia	6	No complications reported
Kramer 2007 <sup>27</sup>	1	2	8	Ectodermal dysplasia	Oligodontia	2	No complications reported
Mass 2007 <sup>7</sup>	1	2	16	Williams-Beuren syndrome	Missing teeth	10 m	No complications reported
McMillan 1998 <sup>22</sup>	1	2	8	Ectodermal dysplasia	Anodontia	1	No complications reported
Ritto 2009 <sup>5</sup>	1	11	16	Ectodermal dysplasia	Oligodontia	3	No complications reported
Rossi 2003 <sup>10</sup>	1	1	10	Dental trauma	Missing teeth	15	Infra-occlusion
Singer 2012 <sup>12</sup>	1	7	11	Ectodermal dysplasia	Oligodontia	20	Change in implant positioning, periimplantitis, bleeding on probing
Wagenberg 1998 <sup>23</sup>	1	9	13.8–15.6	Congenital absence	Oligodontia	6	No complications reported
Jofre 2012 <sup>33</sup>	1	1	10	Dental trauma	Missing tooth	6	Infra-occlusion, lack of retention of the crown
Westwood 1996 <sup>20</sup>	3	5	13.10–16.2	Congenital absence	Missing tooth	1.2	Infra-occlusion, implant exposed in the sinus, bone loss, restoration loosening
Woo 2003 <sup>25</sup>	1	2	14	Papillon-Levefre syndrome	Missing teeth	1	No complications reported

Table 4  
Surgical and prosthetic procedures of cohort studies.

Author, year, reference	Operation					Prosthetic procedure	
	Dental implant	Diameter (mm)	Height (mm)	Placement site	Region	Prosthesis	Loading
Bergendal 2010 <sup>28</sup>	Branemark System <sup>®</sup> Standard Implant, and MK III TiUnite	3.3; 3.75	10–13	Maxilla and mandible	Anterior and posterior region	Not reported	Not reported
Bernard 2004 <sup>11</sup>	Straumann <sup>®</sup>	Not reported	Not reported	Maxilla	Anterior region	Single crowns	3 months
Brahim 2005 <sup>26</sup>	Not reported	Not reported	Not reported	Mandible	Anterior and posterior region	Not reported	Not reported
Heuberer 2012 <sup>8</sup>	Dental Rootform, Nobel Replace, Nobel Biocare, length 8mm	Not reported	Not reported	Mandible	Interforaminal area	Telescope-supported removable dentures	3 months
Heuberer 2015 <sup>3</sup>	MK IV (TiUnite), MK III (TiUnite), MK II and replace tapered from Nobel Biocare, IMZ <sup>®</sup> from Dentsply	3–5	8–15	Maxilla and mandible	Anterior and posterior region	Full-denture and crowns	Not reported
Lambert 2017 <sup>4</sup>	Dentatus Anew <sup>®</sup> and MDL <sup>®</sup> , Intralock; 2–2.5 × 10–13 mm	2–2.5	10–13	Maxilla and mandible	Anterior region	Single crowns	Directly after the surgical procedure
Thilander 2001 <sup>1</sup>	Branemark System <sup>®</sup> , Nobel Biocare length 10–20mm	Not reported	Not reported	Maxilla and mandible	Upper central and lateral incisors, canines and premolar, lower incisors, canine and premolars	Single crowns and fixed prosthesis	5–7 months

Table 5  
Surgical and prosthetic procedures of case reports and case series.

Author, year, and reference	Type	Diameter (mm)	Height (mm)	Placement site	Region	Prosthesis	Loading (after implant placement)
Alcan, 2006	Dentsply Frialit	Not reported	Not reported	Mandible	Interforaminal area	Fixed bridge crowns	3 months
Becktor, 2001	Nobel Biocare, Branemark system®	Not reported	10–15	Maxilla and mandible	Maxilla: anterior and posterior region; Mandible: interforamina area	Maxillary fixed/removable prosthesis and fixed mandibular prosthesis	After 10 months
Bergendal, 2015	Branemark System® standard implant	3.75	10–13	Mandible	Interforaminal area	Overdenture	8 months
Filius, 2014	Standard SLA Implants, Straumann®	Not reported	10–14	Mandible	Interforaminal area	Mandibular overdenture	3 months
Giannetti, 2010	Not reported	13	Not reported	Maxilla	Anterior region	Single crowns	3 months
Guckes, 1997	IMZ® Pressfit, Interpore	Not reported	Not reported	Mandible	Interforaminal area	Mandibular overdenture	2 months
Huang, 2014	ICE™, Osseotite®, Biomet 3i	3.25–3.75	13–15	Maxilla and mandible	Maxilla: posterior region; Mandible: interforaminal area	Mandibular fixed implant-supported denture and maxillary removable denture	Not reported
Kearns, 1999	3i Implant Innovations Nobelpharma	Not reported	Not reported	Maxilla and mandible	Maxilla: anterior region; Mandible: interforaminal area	Fixed and removable prostheses	4 months in maxilla and 6 months in mandible
Kilic, 2015	Endure MDI	2.9	13	Mandible	Interforaminal area	Mandibular overdenture	4 months
Kramer, 2007	MKIII, Nobel Biocare	3.75	13	Mandible	Interforaminal area	Mandibular overdenture	3 months
Mass, 2007	IPI, Nobel Biocare	1.8	18	Maxilla	Anterior region	Provisional crowns	10 days
Mc Millan, 1998	MK I, Nobel Biocare	Not reported	Not reported	Mandible	Interforaminal area	Hybride overdenture	4 months
Ritto, 2009	Nobel Biocare	Not reported	Not reported	Maxilla and mandible	Anterior and posterior region	Fixed bridges	8 months
Rossi, 2003	Frialit Tübingen	4	Not reported	Maxilla	Anterior region	Single crowns	6 months
Singer, 2012	Nobel Biocare	3.75	10–13	Mandible	Anterior and posterior region	Fixed dental prosthesis divided into right and left segments	9 months
Wagenberg, 1998	Nobel Biocare	2.9–3.75	10–15	Maxilla and mandible	Anterior and posterior region	Single crowns	7 months
Werner, 2015	MTI Transitional implants, 1.8 mm	1.8	Not reported	Maxilla	Anterior region	Single crown	Not reported
Westwood, 1996	Bivent implant; APM-Sterngold; Calcitek,	3.25–3.5	10–15	Maxilla	Posterior region	Single crown	7–9 months
Woo, 2003	Branemark, Nobel Biocare,	4	13	Mandible	Interforaminal area	Overdenture	4 months

that the restorative procedures allowed the jaws to grow to completion: two<sup>12,24</sup> reported the fabrication of a prosthesis that was divided at the midline, and Alcan et al<sup>35</sup> made teeth wider to improve chewing.

#### *Complications related to the placement of dental implants*

Nine studies showed no surgical or prosthetic complications during the follow-up period.<sup>5,7,9,21–23,25,27,32</sup> The main complication reported for single crowns and restorations supported by fixed implants installed in the maxilla, was infraocclusion of the implant-supported prosthesis.<sup>1,10,11,19,20,24</sup> For the lower arch, three studies reported rotation of the dental implant as a result of mandibular growth.<sup>12,29,34</sup> As far as the survival rate was concerned, the maximum percentage loss of implants was 23.4%. Two further studies reported prosthetic complications related to loosening of an implant-supported restoration.<sup>20,33</sup>

#### *Within-study risk of bias*

In general, the risk of bias was high, which could be explained by the different study designs. For example, none of the cohort studies presented unbiased assessments or calculated sample size, and some of the case reports and case series failed to describe the patients' demographic characteristics and histories (Appendices E and F) (supplemental data).

### **Discussion**

Our findings suggested that the use of dental implants in children and adolescents is susceptible to surgical and prosthetic complications during the growth phase. These were mostly related to growth of the jaw, which can lead to changes in the position of the implant in both vertical and horizontal directions. In addition the survival rate of dental implants was lower than that reported for adult and elderly patients.<sup>36,37</sup> Nonetheless, rehabilitation with dental implants was considered to be reliable for adolescents.<sup>3</sup> Additional clinical studies with long-term follow-up, therefore, such as the development of guidelines for dental implants for patients in the growth phase, would help to improve the planning of treatment and prevent future complications.

The conditions most commonly found that were related to the absence of teeth were ectodermal dysplasia and dental trauma. In the patients with ectodermal dysplasia, the minimum age for placement of dental implants was 3 years old, and for the dental trauma it was 10 years old.<sup>10,32,33</sup> Bergendal et al<sup>28</sup> evaluated placement of dental implants in this age group, and reported a lower survival rate for those with ectodermal dysplasia (9/14 implants, 64%) than for those with dental trauma (2/36 implants, 6%). The authors claimed that one possible reason for the failures was the small size of the

jaw in the younger patients, which hampered the surgical procedure.

#### *Maxillary growth*

The maxilla is particularly influenced by vertical growth, which moves the maxilla down in patients up to 18 years old. However, horizontal growth does not alter the form of the anterior region, although resorption can occur leading to resorption of buccal bone. Sagittal growth must also be considered, particularly in patients younger than 10 years old, because the midline changes as a result of maxillary sutural growth.<sup>38,39</sup>

Only one study<sup>24</sup> reported placement of dental implants in the anterior region of the maxilla in patients less than 10 years old. However, the fabrication of a prosthetic bar splinted in the midline allowed for stability of treatment. None of the remaining studies reported changes in sagittal or horizontal growth. Conversely, infraocclusion of dental implants as a result of vertical growth was reported in six studies.<sup>1,10,11,20,24,33</sup> For example, Jofre and Werner<sup>33</sup> reported a relation between the lack of retention crowns and a vertical discrepancy between the restoration and the adjacent teeth. In addition, an implant placed posteriorly was exposed in the sinus in a clinical case reported by Westwood and Duncan.<sup>20</sup>

#### *Mandibular growth*

The mandible has more pronounced sagittal, than transverse or vertical, growth. Although transverse growth ceases before the permanent canines erupt, with no changes expected after that, the bone grows anteriorly in the premolar region over a longer period, which could result in lingual positioning of the dental implant.<sup>39</sup>

The main concern about the changes in the positioning of the implant was rotational growth of the mandible, which changes the relation between the dental implant and the adjacent teeth. However, the placement of dental implants in the anterior region of the mandible seems to be safer than in the maxilla. Only two of the studies<sup>29,34</sup> in which the dental implant was placed in the interforaminal area reported changes in rotation of the implant.

#### *Recommendations*

Some research workers have claimed that treatment with dental implants should be postponed until the jaw has stopped growing. However, this type of treatment may be an alternative in specific cases, provided that the balance between the patient's needs and the prognosis is considered. As far as planning treatment is concerned, the use of a cephalometric analysis is recommended to confirm the patient's growth phase before the dental implant is placed. A multidisciplinary approach to treatment should be used for each case individually.<sup>13,39</sup>

The findings of this study show that in those patients in whom teeth are missing as a result of dental trauma or congenital aplasia, implants may be indicated for the anterior regions of the maxilla and mandible provided that a minimum age is considered based on the patient's condition. For maxillary implants, a minimum age of at least 10 years is recommended to avoid structural, growth-related complications. One must also consider the fact that the risk of passive eruption seems to be lower in patients over 15 years of age. In addition, placement of an implant in a more coronal position is recommended to avoid infraocclusion of the implant.<sup>4</sup>

Because of the limited number of studies, we can make no recommendations for the posterior region. However, in all cases, periodic follow-up and adjustments to implant-supported prostheses are required until growth has finished.

#### Limitations of the study

The main limitation was the lack of any controlled studies related to the issue. Although long-term follow-up was stated by many studies, the results were mainly supported by case reports. A deeper analysis of patients by growth-phase is required to understand better the relations between the growth of the jaw and complications of implants. Further studies are required to define a specific protocol for the placement of dental implants in growing jaws.

#### Conclusions

Dental implants that are placed in growing jaws are susceptible to modifications in positioning as a result of growth of the jaw. Nevertheless, in certain circumstances this treatment may be suitable for growing patients, provided that it is done cautiously with consideration of the growth phase, and maintenance consultations are provided.

#### Ethics statement/confirmation of patients' permission

Neither ethics approval nor patients' permission required.

#### Conflict of interest

We have no conflicts of interest.

#### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.bjoms.2019.04.011>.

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