CLINICAL ORAL IMPLANTS RESEARCH

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Dental implants are a viable alternative for compensating oligodontia in adolescents

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Key words: children, growth, young dentition

Abstract

Objectives: To clinically and radiographically evaluate dental implant treatment in adolescents with extensive oligodontia.

Methods: Patients with more than nine permanent teeth congenitally missing and implant treatment before the age of 16 years were included. Clinical follow-ups involved bleeding on probing, plaque index and peri-implant probing value. The peri-implant bone level was analysed on panoramic radiographs at time of implant treatment and at follow-up. Characteristics of the dental implants and patients were retrieved.

Results: This study involved 18 patients (nine males, nine females) having 71 dental implants. The lower left premolar was predominantly missing. The mean age at the time of dental implant treatment was 12.5 (±2.6) years. The bleeding on probing value was determined negative on 44%. The mean pocket depth was 3.6 (±1.1) mm. The peri-implant bone level correlated significantly negative with the age at time of implant placement ($r = -0.346$, $P = 0.004$). The region of implant habits had no influence on peri-implant bone level. Dental implant treatment in adolescents resulted in a survival rate of 89% (63/71) and a mean loading time of 11.0 (±4.1) years. The implant crowns to be renewed resulted in 54% (9 of 18 patients, 38 of 71 crowns) after a period of 7.8 ± 4.5 years.

Conclusion: Dental implant treatment in maturing adolescents with extensive oligodontia before is supported by the data of the present study. Providing that other treatment options are considered, the areas of skeletal growth are respected and the patients are well informed. To enhance quality of life of growing children with oligodontia clinicians are asked to evaluate their long-term outcome on dental implant treatment in adolescents.

The occurrence of oligodontia in the western world is estimated to be as high as 8.4 in 10,000 people (Bergendal et al. 2006). Missing teeth may pose not only impairment for patients in their social environments (such as school, sports, social network) but additionally may be the cause for difficulties in mastication and speech. Although tooth substitution by various prosthetical means has been practiced for the last several decades, no expansive studies on the efficacy of dental implants have been published to date. As the use of dental implants in maturing individuals is rather rare, it implies that prospective long-term studies are similarly scarce. Literature searches revealed that most of the presented studies are case reports. Nevertheless, the issue of treating oligodontia in adolescents has often remained underestimated. Hence, there is an urgent need to assess the success and survival rate of implants in maturing individuals.

The prospect of dental implant treatment (DIT) to recover the stomatognathic system (mouth and jaws) in maturing individuals has often been discussed; however, a generally accepted conclusion regarding its necessity has not yet been reached. Among experts, there are two divergent opinions; on the one hand, some practitioners recommend DIT following completion of dento-facial growth. Considering the fact that dental implants act like ankylosed teeth, they affect normal dento-alveolar development (Lekholm 1993; Oesterle et al. 1993; Cronin et al. 1994; Odman et al. 1991, Thilander et al. 2001). On the other hand, other authors recommend that the optimal time point for DIT should be somewhat earlier already in the final phase of growth, in girls at the age of 15 and

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Date:
Accepted 30 November 2013

To cite this article:
Heuberer S, Dvorak G, Mayer C, Watzek G, Zechner W. Dental implants are a viable alternative for compensating oligodontia in adolescents.
Clin. Oral Impl. Res. **26**, 2015, e22–e27
doi: 10.1111/clr.12323

boys a few years later (Scholz & d'Hoedt 1984; Mackie & Quayle 1993; Kupietzky & Houpt 1995). A team of experts concluded that in cases of anodontia and extensive oligodontia oral implants may be inserted prior to the onset of pubertal growth (Bergendal et al. 1996). In addition, experts recommend applying DIT to edentulous mandibles of children already before school age (Bergendal et al. 1998). Patients with more than nine congenital missing teeth demonstrated severe changes to the normal skeleto-dental pattern and that the absence of the incisors had a predominant influence on the development of this skeleto-dental configuration (Ben-Bassat & Brin 2003, 2009).

The present retrospective study was designed to evaluate the outcome of DIT in juvenile jaws, under the age of 16 years, with extended congenital permanent tooth absence (more than nine permanent teeth), and the parameters considered for analysis included peri-implant bone level, patient age and time of implant placement, and the success and survival of the implantation, among others. The aim was to investigate DIT in young individuals with an extensive form of oligodontia to enhance their daily life accompanied by mastication, speech and aesthetical aspect.

Material and methods

Of 550 patients registered with tooth agenesis at the Bernhard Gottlieb University Clinic of Dentistry of the Medical University of Vienna, subjects with more than nine congenital missing teeth and a DIT before the age of 16 years (ongoing skeleto-dental development) were selected. These patients were invited to a follow-up examination. Informed consent of each patient and approval of the Medical University Vienna ethical review board was obtained (EK NR: 215/2009).

Panoramic radiographs (x-ray) for peri-implant bone loss and implant position during maturing, peri-implant probing value (pocket depth), bleeding on probing and plaque index were evaluated. Information about gender, smoking status, position of the missing teeth, age at time of DIT, type, length and diameters of the dental implants, regions of implant placement as well as success and survival outcome was gathered. Baseline evaluation of the bone level and the implant position were carried out at the time of surgery and at follow-up examination. In addition, the surrounding bone level was measured and compared on panoramic x-rays (rotational extracorporal tomography) at both time points. All measurements of the peri-implant bone loss included the distance from the first bone-to-implant contact to the implant–abutment interface at the mesial and the distal aspects of each implant (Fig. 1a). Two independent specialists performed evaluation to minimize inter-examiner error. The implant position during maturing was evaluated measuring the centre of the implant–abutment interface to a reference line (line between distal cusps of the lower first molars). For comparison, the distance of the lower left canine (distal cement–enamel junction) to reference line was measured. Patients, who did not follow the invitation, even they were contacted by mail and phone several times, were also included providing that all data could be

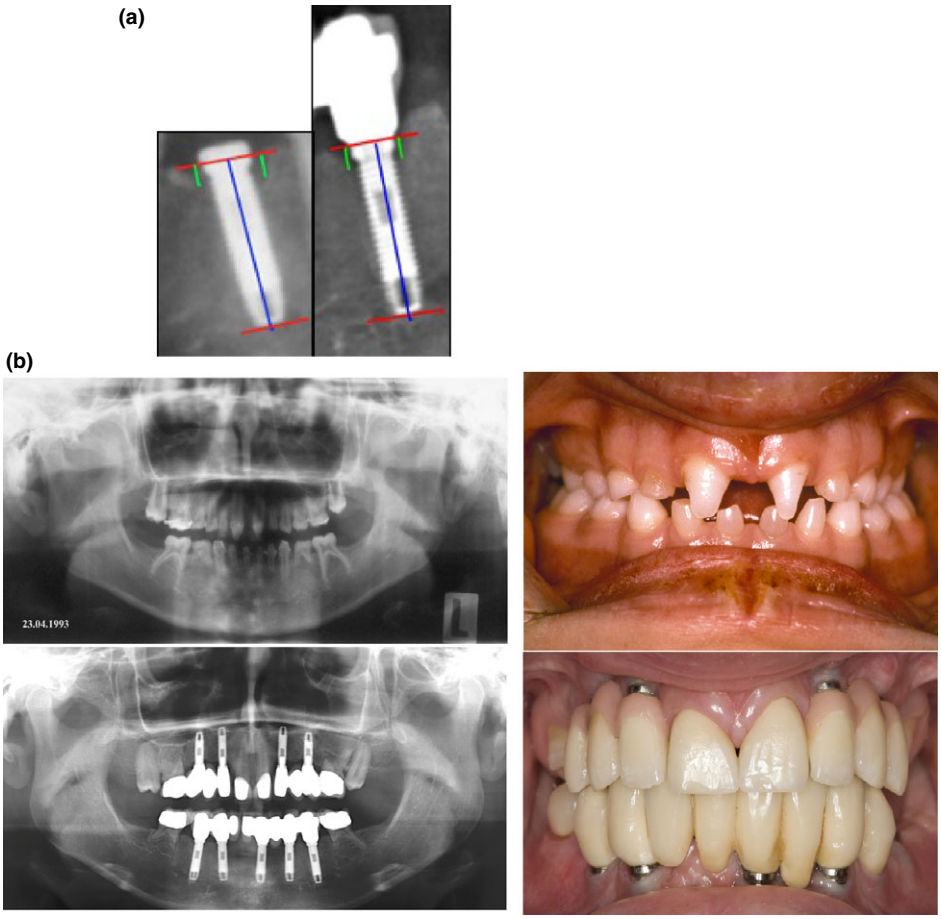

Fig. 1. Radiographic analysis, (a) Measurement of the dental implant at time point of DIT and at follow-up; distance from the first bone-to-implant contact to the implant–abutment interface at the mesial and the distal aspects of each implant. (b) Upper line: 10-year-old patient with 22 permanent teeth congenital missing. Age at time of dental implant treatment between 10–12 years. Lower line: Same patient at the age of 24 years.

gathered from their records. Their x-rays at time of DIT and of their last consultation were retrieved. Further information (pocket depth, bleeding on probing, smoking habits, prosthetic implant loading) was gathered from the patients' records.

Statistical analysis

The statistic involved the descriptive statistic to illustrate the distribution of gender, age at time of DIT, tooth agenesis including type of tooth and quantity, implant system, bleeding on probing, the plaque index, the peri-implant probing value, implant position and prosthetic restoration. In addition, the correlation of bone resorption between the mesial and the distal aspect of the dental implants to (1) the quantity of tooth agenesis and (2) the age at time of DIT was evaluated using the Spearman's rho. A nonparametric method, the Kruskal–Wallis test, was used to compare bone resorption at the mesial and distal aspect of the dental implants to the (1) implant region, (2) type of implant, (3) diameter of implant, (4) surface of implant, (5) length of implant, (6) plaque index and (7) smoking habits. The subgroups of the varying implant systems compared to the mesial and distal bone resorption were tested using post hoc analysis. The predetermined significance level was set at 5% ($P < 0.05$).

The inter-rater reliability was checked with a Pearson correlation coefficient. The method error of the measurement of the mesial and distal implants surrounding bone loss in-between the two specialists was tested using Dahlberg's formula.

Results

The mean age at time of implantation was 12.5 (±2.6) years

The analysis of the 550 patients resulted in 18 patients with more than nine congenital permanent teeth missing and a DIT before the age of 16 years. In total, 71 dental implants were placed, between one and nine dental implants per patient. The youngest patient was 6 years old. The results showed that the gender distribution was 9 to 9 and the quantity of missing congenital permanent teeth ranged from 10 to 26 teeth. Males suffered from a more extensive form of oligodontia compared with females. The analysis showed that 45% of the patients were between 14 and 16 years and 32% between 10 and 12 years at time of DIT (Fig. 2). The predominant missing tooth was represented by the lower left second premolar, followed by the lower left first incisor, the lower right second premolar and the upper second left and right premolars. In one adolescent, bone augmentation in the upper jaw was carried out prior to implant placement. Three of 18 were smokers. The restoration in four patients was an implant-supported full denture, and all the other 14 patients were restored by implant crowns.

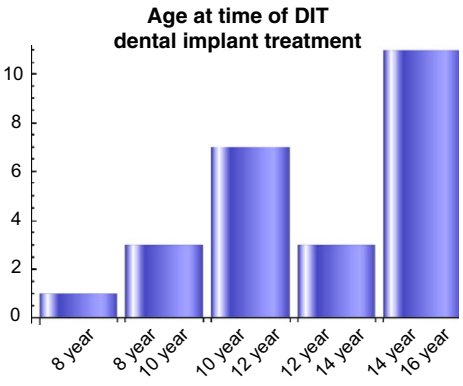

Fig. 2. Main age at time point of DIT was between 14 and 16 years.

Hence, it would appear that males were more susceptible to tooth agenesis and that average age of DIT was in the mid-teens, and it would also be interesting to determine the rate of success and survival of implants in these patients.

The survival rate of dental implants growing children is 89% with a mean loading time of 11 (±4.1) years

As mentioned above, this study comprised 71 dental implants, categorized into five groups and two different manufacturers. Using implants made by Nobel Biocare, two were of the type MK IV (TiUnite); 23, MK III (TiUnite); 26, MK II; and 16 implants were of the type Replace Tapered. In addition, four IMZ implants were made by Dentsply Friadent (Table 1).

The results revealed that the diameter of the dental implants amounted 3–5 mm, the length ranged from 8 to 15 mm. The surfaces of the dental implants differed in moderately rough, minimally rough and rough.

In total, three dental implants (3 MK II (TiUnite)) had to be removed, but one could be successfully replaced, six implants will be removed (2 MK IV (TiUnite), 2 MK II, 1 Replaced Tapered) because of bone loss during follow-up period. The dental implant loss rate achieved 11%.

According to the documented recall rate of 72%, five patients (total of 15 dental implants) did not follow our repeated invitations for clinical examination because of moving to another city/country or lack of response.

The bleeding on probing value was evaluated in 13 patients, 54 dental implants. The bleeding on probing value was determined negative on 31 dental implants (44%) and positive on 23 dental implants (32%).

The plaque index was categorized in (1) little, (2) moderate and (3) plenty and proved by scraping off a probe at the margin of the gingival. The adolescents showed little plaque on 30 dental implants (42%), moderate plaque on 20 dental implants (28%), plenty plaque on four dental implants (6%) and 17 dental implants (24%) could not be evaluated because of implant failure or impossible clinical examination.

The sounding probe was tested using a WHO-testing probe (3.5–5.5–8.5–11.5), and the depth was categorized in (1) 0–3.5 mm, (2) 3.5–5.5 mm, (3) >5.5 mm and (4) not available. Finally, the pocket depth of 35 dental implants (49%) was under 3.5 mm, 14 dental implants (20%) were found in group (2) and 5 dental implants (7%) in group (3). Again, 17 dental implants (24%) could not be tested. The mean probing depth was 3.6 (±1.1) mm.

Thus, the success rate of the dental implants was evaluated according to the following criteria: peri-implant probing value ≤5 mm, bleeding on probing (BoP) negative, bone loss <0.2 mm (Karoussis et al. 2004). The result of these success criteria was evaluated on 54 dental implants, 17 dental implants could not be included because of loss (2) or missing clinical examination (15). Therefore, the success rate resulted in 17% (9/54, 5 patients), whereas the survival rate resulted in 89% (63/71, 16 patients). The mean loading time of the dental implants was 11 (±4.1) years; 1 year was the shortest period and 18 years the longest at time of investigation. As these failed implants were associated with surrounding bone loss, this prompted us to investigate peri-implantitis.

Table 1. **Seventy-one dental implants, categorized into five groups and two different manufacturers**

Manufacture	Implant type	Quantity
Nobel Biocare	MK IV (TiUnite)	2
Nobel Biocare	MK III (TiUnite)	23
Nobel Biocare	MK II	26
Nobel Biocare	Replace Tapered	16
Dentsply Friadent	IMZ	4

Peri-implantitis risk is highest in younger patients

As five patients could not be examined clinically, it was also of interest to achieve radiographic parameters using the panoramic radiograph at time of DIT and at time of follow-up. Hence, the x-rays at both time points of all the 18 patients were retrieved to measure the peri-implant bone level.

Spearman rank correlation coefficients were calculated for distances between bone-to-implant contact and implant–abutment interface mesial and distal and the region of tooth agenesis and the age of implant placement. The particular types of the dental implants were analysed. The mean values of the dental implant surrounding bone loss were as follows: MK II: mesial 1.9 ± 1.8 mm, distal 1.8 ± 1.5 mm; MK III (TiUnite) mesial 1.8 ± 0.8 mm, distal 1.6 ± 0.9 mm; MK IV (TiUnite): mesial 3.8 ± 1.0 mm, distal 3.6 ± 0.7 mm; Replace Tapered: mesial 1.4 ± 0.8 mm, distal 1.5 ± 1.0 mm; IMZ: mesial 0.6 ± 0.6 mm, distal 0.3 ± 0.6 mm. The distal measurement correlates significantly negative with the age at time of implantation ($r = -0.346$, $P = 0.004$), but not with the amount of tooth agenesis. Differently to the result of the distal measurement, the mesial measurement is not significantly correlated neither with the age of implantation ($r = -0.2$, $P = 0.099$) nor with the region of implantation ($r = -0.217$, $P = 0.73$). Not surprisingly was the high significant correlation between mesial and distal implant surrounding bone loss ($P < 0.001$). (Tables 2a and b).

The Kruskal–Wallis test was used to compare the mesial and distal marginal bone level with the implant region which was not significant ($P > 0.05$).

To examine differences between the types of implants, a Kruskal–Wallis test was performed. We found significant differences between the types of implants according to the mesial measurement ($P = 0.045$) as well as the distal measurement ($P = 0.026$). To determine between the types of implants when these differences occur, post hoc t-tests for independent samples were carried out. *P*-values are Bonferroni corrected. We found significant differences between MK IV TiUnite and MK III TiUnite for the mesial measurement ($P = 0.02$) and for the distal measurement ($P = 0.04$). There were also significant differences for the mesial measurements between MK IV TiUnite and Replace select ($P = 0.01$) and between MK III TiUnite and IMZ ($P = 0.09$). The distal measurements only were significant between MK IV TiUnite and Replace Tapered ($P = 0.012$), between MK IV TiUnite and IMZ ($P = 0.004$), between Replace Tapered and IMZ (P 0.045) and between MK III TiUnite and IMZ ($P = 0.010$). However, these values have to be taken carefully, because the sample size of MK IV TiUnite was quite small. The rest of the correlations in-between the implant types were not significant ($P > 0.05$). (Table 3a and b).

The correlations between the mesial and distal implants surrounding bone loss and (1) the implant diameter, (2) the implant surface, (3) the implant length, (4) the plaque index and (5) the smoking habits were in all these evaluations not significant ($P > 0.05$).

The inter-rater reliability was checked with a Pearson correlation coefficient. The measurements of the two specialists are highly correlated ($r = 0.969$, $P \leq 0.001$). The method error of Dahlberg's formula for the mesial implants surrounding bone loss was 0.159 mm and for the distal bone loss 0.164 mm. Therefore, we can assume that the error had no essential impact on the results.

The implants distance more from the reference line compared to the lower left canine

The implant position included the evaluation of 14 patients (49 dental implants), 4 patients (22 dental implants) had to be excluded because the lower molars for the reference line were missing. The lower left canine was present in 10 of these patients. The implants distanced 3 ± 4 mm to the reference line during a time period of 8.6 ± 5.2 years, whereas the lower left canine approached 1.0 ± 4.3 mm to the reference line. The results showed that 54% of the implant crowns (nine of 18 patients, 38 of 71 crowns) had to be renewed after a period of 7.8 ± 4.5 years, five of these nine patients (18 implant crowns) received their new restoration after the age of 20 years.

Table 2. **Spearman rank correlation coefficients were calculated for distances between bone-to-implant contact and implant–abutment interface mesial and distal and (a) the region of tooth agenesis and (b) the age of implant placement**

	Tooth agenesis	Mesial bone loss	Distal bone loss
(a)			
Tooth agenesis	1		
Mesial bone loss	−0.126	1	
Distal bone loss	−0.027	0.781*	1
	Age at time of DIT	**Mesial bone loss**	**Distal bone loss**
(b)			
Age at time of DIT	1		
Mesial bone loss	−0.200	1	
Distal bone loss	−0.346*	0.781*	1

*Correlations are significant at $P < 0.01$.

Discussion

Although traditionally dentures have been used in young people suffering from extensive oligodontia, here we showed that dental implants represent a viable alternative to this procedure. The advantages of dental implants supported overdentures include stability, maintenance, comfort as well as the possible permanent masking of an extremely compromising defects.

Previously, studies reported of relationship of multiple permanent teeth missing and malformation of the skeleto-dental pattern (Ben-Bassat & Brin 2009). Thus, an early diagnostic including orthopantomography before the age of 14 years in assumption of tooth agenesis is recommended (Yap & Klineberg 2009).

However, the treatment of young individuals with tooth agenesis is very particular and challenging within its limitations like underdeveloped bone volume, young age, skeleto-dental malformation and ongoing skeletal growth. The aim is to improve the stomatognathic system in its function and aesthetic (Kearns et al. 1999). Therefore, all kind of treatment opportunities should be considered, like orthodontic space closure, autologous teeth transplantation, prosthetic rehabilitation and dental implant treatment (DIT).

The outcome of DIT in children was studied previously by sending a questionnaire to the specialist clinics and published that the failure rate of oral implants reported for adults was only slightly minor than that in children treated due to congenital absence of permanent teeth (Bergendal 2008).

If the strategy of DIT is chosen, a careful preoperative treatment planning by three-dimensional analysis is indicated to choose the adequate implant diameter and length. The outcome of the dental implant survival also depends on the principles of atraumatic surgery using sufficient cooling and a screw tape implant and on the use of the

Table 3. **(a) The Bonferroni corrected post hoc t-test was used for testing the significance of the mesial bone loss and the different dental implant groups. (b) The Bonferroni corrected post hoc t-test was used for testing the significance of the distal bone loss and the different dental implant groups**

	Sample size	Mean ± SD (in mm)	MK IV TiUnite	MK III TiUnite	MK II	Replaced Tapered
(a)						
MK IV TiUnite	2	3.83 ± 1.03				
MK III TiUnite	21	1.77 ± 0.78	$P < 0.05$			
MK II	26	1.89 ± 1.78	n.s.	n.s.		
Replaced Tapered	16	1.43 ± 0.77	$P < 0.05$	n.s.	n.s.	
IMZ	4	0.60 ± 0.58	n.s	n.s.	n.s.	n.s.
(b)						
MK IV TiUnite	2	3.60 ± 0.71				
MK III TiUnite	21	1.57 ± 0.86	$P < 0.05$			
MK II	26	1.76 ± 1.50	n.s.	n.s.		
Replaced Tapered	16	1.47 ± 1.03	n.s.	n.s.	n.s.	
IMZ	4	0.30 ± 0.60	$P < 0.05$	n.s.	n.s.	n.s.

n.s., not significant; $P < 0.05$ significant.

appropriate implant system for the underdeveloped jaws. The patients must be well informed that the implant treatment in maturing patients might be a temporary solution and that the implant crown might be renewed or the dental implant removed altogether (Kearns et al. 1999).

Ongoing skeletal growth is one of the main limiting factors of DIT. Hence, some bony areas should be respected. DIT is not recommended in the upper region of the incisors, due to transversal growth. The median palatal suture ossifies at the earliest age of 15 years or even later (Op Heij et al. 2006). Furthermore, the periodontal ligament of the tooth presents the main difference to the dental implant. The dental implant is united and fixed with its surrounding bone and does not follow dento-alveolar development (Odman et al. 1991). Hence, experts concluded that dental implants in the upper incisor region might be disadvantaged because of the resulting infraocclusion (Thilander et al. 2001). This conclusion is in agreement with the finding that growth proceeds even in adult age (Oesterle & Cronin 2000). A previous study of our team recommended that in cases of extensive oligodontia, DIT might be favourable even in young children when considering the region of the implant placement (Heuberer et al. 2012). The front area of the lower jaw was chosen for DIT based on the fact that the symphysis ossifies before the age of 6 years (Bergendal 2008). The present results showed that with the time the lower left canine was more cranial than the dental implants. However, these results have to be regarded with caution. Firstly, the number of patients (14/18) is rather small. Secondly, six of the 14 patients were treated by orthodontics during the period between the two radiographs. Thirdly, the occlusal plane was not possible as reference line, because the lower first incisors were predominant missing. Therefore, the reference line was the intercuspidal connection of the lower first molars.

The quantity of implant crowns to be renewed was 54% (38/71, nine patients), half of the crowns were renewed after the age of 20 years, after skeleto-dental growth.

Thilander et al. examined 18 adolescent patients with dental oral implants during a period of ten years without any implant loss. The present study showed a survival rate of dental implant treatment of 89% with a mean loading time of 11 (±4.1) years that agrees with the literature (Durstberger et al. 1999; Kearns et al. 1999). Further recent studies also stated that an implant-supported prosthetic construction is a good treatment alternative in adolescence with extensive tooth agenesis, provided the fact that skeletal growth is almost completed.

The present study showed a mean implant surrounding bone loss of 1.73 mm at the mesial aspect and distal of 1.60 mm. Finnema et al. (2005) reported similar results, a difference of the marginal bone level of about 1.6 mm. The age at time of implantation was negatively correlated with the bone loss. This result underlies the opinion to start DIT about the end of pubertal growth, excepted are patients with an extensive form of oligodontia (Bergendal 2008).

From an ethical point of view, the patient population manifesting severe oligodontia ranges from very young children to adolescents. Our youngest patient at time of implant placement was 6 years old. To enable an atraumatic treatment in early childhood, the surgery should be carried out in general anaesthesia. It is recommended to treat this patient population only in specialized centres in collaboration with an interdisciplinary team (surgeon, orthodontist, prosthodontist). From the social point, DIT is accompanied with pain, healing period, absence from school and costs. Therefore, it should be well considered for each case if DIT is the optimal treatment option.

Since 1989, the Bernhard Gottlieb University Clinic of the Medical University of Vienna aims to improve the documentation of the treatment of patients with tooth agenesis. Hence, our centre overlooks of a register including more than 550 patients with tooth agenesis. Out of this specific patient pool, the criteria requiring at least more than nine congenital missing permanent teeth and an age below 16 years meant that only 18 patients could be involved in the present study. The recall rate for this long-term clinical follow-up resulted in satisfying 72%, even though the patients were contacted by phone and mail several times. Unfortunately, the small study population (71 dental implants) limits statistical significance of the results of our investigation. The present study is a two-dimensional analysis using OPTGs. Three-dimensional analysis was performed presurgically for the implant treatment plan. After dental implant placement, OPTGs were used for follow-up, considering that the longest observation period is 18 years. Within its limits, the data of this study were evaluated for a period of nearly 20 years. Thus, clinicians are asked to continuously investigate the long-term outcome of DIT in children to improve the quality of treatment strategies and to avoid complications. These data allow us to improve dental treatment to youngsters, when aesthetic appearance in social settings such as school has an incalculable impact on their sense of worth and social acceptability.

Conclusion

We conclude that dental implant treatment (DIT) in adolescent people has been rarely applied in the last two decades. The present results demonstrate long-term survival of dental implants in young individuals. However, more long-term research is needed to further enhance dental implant treatment in maturing people with extensive oligodontia.

Conflict of interest

The author declares no conflict of interests in relation to this study.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. CONSORT 2010 checklist of information to include when reporting a randomised trial*.