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Clinical Outcomes of Dental Implant Therapy in Patients With Ectodermal Dysplasia: A Narrative Review

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Abstract

Ectodermal dysplasia (ED) comprises a heterogeneous group of inherited disorders that affect ectoderm-derived structures, including the teeth. Hypodontia, oligodontia, and anodontia are frequently accompanied by deficient alveolar ridge development, which limits the retention and stability of conventional removable prostheses. This narrative review summarizes the literature on dental implant therapy in patients with ED that was published between 1987 and 2025 and identified through PubMed, with emphasis on implant survival, complications, bone augmentation, growth-related considerations, patient-reported outcomes, and long-term maintenance. The available evidence indicates that implants can achieve favorable functional and prosthetic outcomes in appropriately selected patients. Short-term survival is generally high, but cumulative survival declines with longer follow-up, and outcomes vary with patient age, implant site, bone availability, and treatment protocol. Implants placed in the anterior mandible show consistently higher survival than maxillary implants. Because osseointegrated implants do not follow skeletal growth, implants placed in growing children may become infraoccluded or malpositioned, and removable prostheses therefore remain important during growth. Alveolar deficiency frequently necessitates augmentation, although graft-avoiding options such as zygomatic implants have been described. Despite frequent complications, patients report high satisfaction with implant treatment. Evidence remains limited because of the rarity and phenotypic heterogeneity of ED, small study populations, and predominantly observational designs. Treatment should therefore be individualized and planned by a multidisciplinary team, with careful consideration of skeletal maturity, bone availability, prosthetic requirements, and the capacity for long-term maintenance.

Categories: Dentistry
Keywords: anodontia, bone augmentation, dental implants, ectodermal dysplasia, hypodontia, implant survival, oligodontia, pediatric dentistry, prosthetic rehabilitation

Introduction And Background

Ectodermal dysplasia (ED) comprises a heterogeneous group of inherited disorders characterized by abnormal development of two or more ectoderm-derived structures, including the hair, nails, skin, sweat glands, and teeth [1,2]. Numerous clinical entities have been described, and current classifications increasingly organize them according to the underlying gene and molecular pathway rather than clinical features alone [2]. Hypohidrotic ectodermal dysplasia (HED), most often X-linked and caused by variants in the EDA gene, is the most common form and is classically associated with sparse hair, reduced sweating, and severe tooth agenesis [1,2]. Each form of ED is rare, which is why most clinical centers treat few affected patients and why the evidence on dental rehabilitation consists largely of small series [1,3]. The dental manifestations vary considerably among affected individuals and range from hypodontia to oligodontia and, in severe cases, complete anodontia [1,3,4]. The teeth that do develop are frequently conical or otherwise malformed [1,3]. Together, these abnormalities have substantial functional, esthetic, and psychosocial consequences that often become apparent in early childhood [3,4].

Because alveolar bone develops in association with the teeth, the absence or severe reduction of the dentition also impairs development of the alveolar processes. In edentulous regions, the ridge is often narrow and deficient in both height and width, which complicates both conventional and implant-supported rehabilitation. Affected patients may therefore experience difficulties with mastication, speech, prosthesis retention, and facial appearance. Conventional removable prostheses remain an important treatment option, particularly in growing children, but their retention and stability may be compromised when few or no teeth are available for support [3,4]. Dental implants offer an alternative means of improving prosthesis retention and stability in appropriately selected patients, and both implant-supported overdentures and fixed implant-supported prostheses have been used when conventional prostheses prove inadequate [5-8]. Implant treatment in ED is nevertheless technically demanding because of limited alveolar bone, unfavorable anatomy, complex prosthetic requirements, and continuing craniofacial growth in pediatric patients [3,5,6].

The timing of implant placement is a particularly important consideration in growing individuals. Unlike natural teeth, osseointegrated implants are functionally ankylosed to the surrounding bone and neither

erupt nor adapt to skeletal growth. Consequently, implants placed during active growth may become infraoccluded or develop positional discrepancies relative to the adjacent dentition and the developing alveolar structures [9-11]. When the available ridge dimensions are insufficient for implant placement, bone augmentation may also be necessary, or graft-avoiding approaches such as zygomatic implants may be considered [6,12].

Because ED represents a group of rare and phenotypically diverse disorders, most of the available evidence derives from case reports, case series, retrospective studies, and systematic reviews of relatively small populations. Reported implant outcomes must therefore be interpreted in light of differences in patient age, ED phenotype, implant site, surgical technique, prosthetic design, and follow-up duration. The purpose of this narrative review is to summarize the literature on dental implant therapy in patients with ED, with particular emphasis on implant survival, surgical and prosthetic complications, bone augmentation, pediatric treatment, craniofacial growth, patient-reported outcomes, and long-term management.

Review

Literature search strategy

This article is a narrative review rather than a systematic review or meta-analysis, and its reporting was guided by the Scale for the Assessment of Narrative Review Articles (SANRA) [13]. PubMed was searched for publications from January 1, 1987, to December 31, 2025. Because the exact date of the original search was not recorded, the search was rerun on October 16, 2026, using the search string (“ectodermal dysplasia”[tiab] OR “Ectodermal Dysplasia”[Mesh] OR oligodontia[tiab] OR anodontia[tiab] OR “Anodontia”[Mesh]) AND (implant*[tiab] OR “Dental Implants”[Mesh] OR “prosthetic rehabilitation”[tiab] OR “bone augmentation”[tiab]) AND 1987/01/01:2025/12/31[dp] AND english[la], which yielded 681 records. The reference lists of relevant articles were also screened, and most of the literature on zygomatic implants, mini-implants, implant-retained overdentures, implant placement in growing patients, and peri-implant disease was identified through this citation searching.

Publications were eligible if they were (1) clinical studies or case series reporting outcomes of dental implant treatment (implant survival or failure, complications, prosthetic results, or patient-reported outcomes) in patients with ED or with severe oligodontia and features of ED; (2) systematic, critical, or narrative reviews of implant or prosthetic rehabilitation in ED; or (3) consensus statements on the dental management of ED. Both adult and pediatric patients were included. Animal and in vitro studies, conference abstracts, and publications not in English were excluded. Of the 681 records, 161 concerned ED, and most were single-case reports. In keeping with the narrative design, individual case reports were not cited separately unless they illustrated a point not covered elsewhere, because they are pooled in the systematic reviews discussed in the following section. Instead, the clinical studies, case series, and reviews most relevant to each topic were selected for discussion. In total, 22 ED-specific studies were included: seven reviews; 12 clinical studies, case reports or case series, or patient surveys; and three consensus statements. We also cited 12 publications for context: six on the genetics, classification, craniofacial growth, and prenatal treatment of ED; five from the general implant literature on implant placement in growing patients, infraocclusion, and peri-implant disease; and one methodological reference. As the studies differed substantially in patient characteristics, implant protocols, outcome definitions, and follow-up periods, the findings were synthesized qualitatively, and no formal risk-of-bias assessment or statistical pooling was performed.

Clinical characteristics relevant to implant therapy

The oral manifestations of ED vary according to the specific genetic and clinical phenotype. Hypodontia and oligodontia are common, whereas severe forms may be associated with extensive tooth agenesis or anodontia, and the teeth that are present are frequently conical, microdontic, or widely spaced [1,4]. Reduced tooth development is typically accompanied by underdevelopment of the corresponding alveolar process. The resulting ridge deficiency may involve reduced width, reduced vertical height, or both, often producing a knife-edge ridge in the anterior mandible and a thin, poorly developed alveolar process in the maxilla. Bone quality also differs: Bergendal et al. specifically drew attention to the dense bone associated with X-linked HED as a factor to be anticipated in surgical planning [14]. These anatomical limitations complicate the fabrication and retention of conventional removable prostheses and may also restrict the number, dimensions, and positions of the implants that can be placed [3,4].

Craniofacial growth is also altered. Dellavia et al. obtained three-dimensional facial measurements in 12 children with HED at 8, 11, 12, and 15 years of age and found that facial growth was initially reduced compared with controls. The difference tended to diminish with age, although facial depth and the middle third of the face remained, and the authors suggested that functional and prosthetic treatment may have contributed to the catch-up [9]. This observation supports early prosthetic rehabilitation in affected children. Some forms of ED are also associated with reduced salivary secretion or xerostomia, which may contribute to oral discomfort, impaired prosthesis tolerance, and increased susceptibility to dental disease [1,3]. Finally, findings obtained in one ED phenotype should not automatically be generalized to all individuals with ED, and many clinical reports describe patients only as having "ectodermal dysplasia" without further specification. Whenever possible, studies should report the specific clinical and genetic phenotype of the included patients [2].

Implant survival and clinical outcomes

Two systematic reviews provide the broadest estimates of implant outcomes in ED. Wang et al. included 96 patients and 701 implants and reported 24-month survival rates of 97.9% in adults and 98.6% in children; the pediatric figure was based on 22 children with a median follow-up of 24 months, and 68% of the adults had undergone bone augmentation before implant placement [5]. Chrcanovic pooled 228 patients and 1,472 implants from 90 publications. Of the 1,391 implants with follow-up data, 72 failed (5.2%), giving an estimated failure probability of 4.5% (95% confidence interval (CI) 3.5% to 5.6%), and the Kaplan-Meier cumulative survival rate at 20 years was 84.6% [6]. Because the mean follow-up was only 42.9 months, very few implants contribute to the 20-year estimate, which should therefore be interpreted with caution. Yap and Klineberg reported survival rates of 88.5% to 100% across the studies they reviewed and concluded that implants placed in patients with ED younger than 18 years carry a higher risk of failure [15].

Among primary studies, the largest prospective trial is that of Guckes et al., who placed 264 implants in 51 persons with ED aged 8 to 68 years using a two-stage protocol. Crude survival was 91% (221 of 243) for implants in the anterior mandible but 76% (16 of 21) for implants in the anterior maxilla; 27% of the participants experienced at least one failure, and all but two failures occurred before or at second-stage surgery [7]. The authors concluded that implants remain a reasonable option in this population but that additional caution is warranted in the maxilla. The primary clinical studies [7,8,12,14,16-22] are summarized in Table *1*, and the systematic and critical reviews [5,6,15,23,24] in Table *2*, with the type of survival measure and the follow-up stated for each.

Study	Design	Population and implants	Follow-up	Outcome (type of measure)
Guckes et al. [7]	Prospective clinical trial	51 patients aged 8-68 years; 264 implants (243 anterior mandible, 21 anterior maxilla)	0-78 months after second-stage surgery	Crude survival: 91% (221/243) mandible vs. 76% (16/21) maxilla; ≥1 failure in 27% of patients
Bergendal et al. [8]	Retrospective national survey	Five children aged 5-12 years; 14 implants	Before loading	Loss before loading: 9 of 14 implants (64%)
Goker et al. [12]	Retrospective clinical study	Nine adults aged 21-56 years; 19 zygomatic implants	Mean 55 months	Survival: 100% (19/19); prosthesis delivered on the day of surgery
Bergendal et al. [14]	Case report	One boy with X-linked HED; two mandibular implants at 6 years and two at 19 years	Three decades	Managed care into adulthood, with additional implants placed at 19 years
Kearns et al. [16]	Clinical cohort	Six patients aged 5-17 years; 41 implants (19 maxillary, 22 mandibular)	Mean 7.8 years after placement	Integrated and restored: 40 of 41 (97.6%); submersion of implants adjacent to developing alveolus in two young patients
Sweeney et al. [17]	Retrospective study	14 patients aged 12-21 years; 61 implants	Variable; 13 implants (21%) not reviewed	Integration rate: 88.5% (54/61); success at follow-up 67.2%; maxillary failures 3/15 vs. mandibular 4/46
Montanari et al. [18]	Cohort study	Nine preteen patients with HED; 18 anterior mandibular implants, sliding-bar overdentures	3-12 years (mean 8.1)	Implant and prosthetic survival and success: 100%; one minor prosthetic complication
Kramer et al. [19]	Case report and literature review	One boy; implants placed at 8 years	Not stated	Authors recommended early implant placement in children with severe hypodontia
Heuberer et al. [20]	Retrospective study	Six children with severe oligodontia (five with signs of ED); 8 palatal onplants in four and 8 mandibular implants in three	Mean 5 years (onplants) and 3 years (implants)	No implant lost; one onplant lost and replaced
Filius et al. [21]	Case series	Four young children with severe oligodontia (included in the ED-only review by Zhu et al.)	Median 5.2 years	No implant lost
Stanford et al. [22]	Patient survey	109 of 253 people with ED responded (43%)	Self-reported	Satisfied or very satisfied: 91%; any complication: 50%; any implant failure: 24%

TABLE 1: Primary clinical studies of dental implant therapy in patients with ectodermal dysplasia

Review	Evidence base	Follow-up	Outcome (type of measure)
Wang et al. [5]	96 patients; 701 implants (22 children)	Median 24 months in children	24-month survival: 97.9% adults, 98.6% children; augmentation before placement in 68% of adults
Chrcanovic [6]	90 publications; 228 patients; 1,472 implants	Mean 42.9 months	Failure: 72 of 1,391 implants (5.2%); failure probability 4.5% (95% CI 3.5%-5.6%); 20-year Kaplan-Meier survival 84.6%
Yap and Klineberg [15]	Critical review of implant studies in ED and tooth agenesis	Variable	Survival range 88.5%-100%; higher failure risk under 18 years
Barve et al. [23]	Four cohort studies and case reports in children	3-8.1 years	Survival range 88%-100% across cohort studies
Zhu et al. [24]	23 studies; 46 patients aged 3-18 years; 192 implants	Variable	Overall survival about 98%; 100% for interforaminal mandibular implants; lower in the maxilla

TABLE 2: Systematic and critical reviews of dental implant therapy in patients with ectodermal dysplasia

These figures should not be read as measures of treatment success. Implant survival and overall treatment success are not synonymous: an implant may remain osseointegrated while the patient experiences prosthetic complications, high maintenance requirements, functional limitations, or growth-related positional changes. Clinical evaluation should therefore encompass implant-related, prosthetic, and patient-reported outcomes.

Pediatric implant therapy

Pediatric implant therapy requires particular caution because of continuing craniofacial growth, and the evidence in children is not uniformly favorable. In the Swedish national survey reported by Bergendal et al., 14 implants were placed in five children aged 5 to 12 years, and nine (64%) were lost before loading; the authors attributed the failures to small jaw size and the conditions at surgery rather than to ED itself [8]. In contrast, Kearns et al. placed 41 implants (19 maxillary and 22 mandibular) in six patients aged 5 to 17 years, and 40 integrated and were restored (97.6%), with an average follow-up of 7.8 years after placement [16]. Sweeney et al. reported that 54 of 61 implants (88.5%) in 14 adolescents and young adults aged 12 to 21 years integrated and could be restored, but five of the 14 patients lost at least one implant before abutment connection; overall success at follow-up was 67.2%, and 13 implants (21%) were not reviewed. Maxillary implants also failed more often than mandibular implants (three of 15 vs. four of 46) [17], which adds to the evidence that the anterior mandible is the more predictable site [7,24].

Successful results have also been reported in young children treated with anterior mandibular implants. Montanari et al. placed two implants in the anterior mandible of nine preteen patients with HED and connected them with a sliding bar, designed so as not to restrict growth, to retain an overdenture; over a mean follow-up of 8.1 years, implant and prosthetic survival were both 100%, and only one minor prosthetic complication occurred [18]. Heuberer et al. treated six children with severe oligodontia, five of whom showed signs of ED, with eight palatal onplants in four children and eight mandibular implants in three; no implants were lost, and one onplant was replaced [20]. Filius et al. reported no implant loss over a median of 5.2 years in four young children with severe oligodontia [21]; this series was included in the review by Zhu et al., which was restricted to patients diagnosed with ED [24]. Kramer et al. described a boy who received implants at 8 years of age and recommended early implant placement in children with severe hypodontia [19], and Bergendal et al. documented three decades of managed care in a boy with X-linked HED who received mandibular implants at 6 and 19 years of age [14].

The most recent systematic review, by Zhu et al., included 23 studies describing 46 patients aged 3 to 18 years who received 192 implants. Overall survival was approximately 98%; implants in the interforaminal region of the mandible showed 100% survival, maxillary implants had lower survival, and complications were more frequent in the youngest children; the authors therefore suggested deferring maxillary implants until early adulthood [24]. Barve et al. reported a survival range of 88% to 100% on the basis of four cohort studies (Kearns, Guckes, Sweeney, and Montanari) [23]. These pooled pediatric figures, however, should be weighed against the Swedish experience. The 98.6% reported for children by Wang et al. is based on 22 children with a median follow-up of 24 months [5], and the Swedish series does not appear to be included in the pool of Zhu et al., since nine failures among 14 implants would not be compatible with approximately 98% survival across 192 implants [24]. The high pediatric figures therefore derive mostly from published, largely successful cases, whereas the only national survey found that 64% of implants placed in five young

children with ED were lost before loading [8]. Consistent with this, Yap and Klineberg concluded that patients younger than 18 years have a higher risk of implant failure [15].

The question of age was addressed directly by an international Delphi study and a subsequent consensus meeting on the rehabilitation of children with ED [25,26]. As summarized by Zhu et al., these supported the placement of anterior mandibular implants from about 7 to 8 years of age in cases where they are necessary [24]. Even so, no single age exists at which implant therapy becomes appropriate for every child with ED. Treatment decisions should take into account skeletal maturity, residual craniofacial growth, implant location, available bone, prosthetic requirements, and the functional and psychosocial needs of the child and family. Informed consent for pediatric implant treatment should explicitly address the possibility of future infraocclusion, the need for prosthetic revision, and, in some cases, implant removal or replacement in adulthood [10,19].

Craniofacial growth and implant position

Because implants are rigidly integrated into bone, they cannot maintain the same relative position as the developing dentition, and infraocclusion may develop as adjacent teeth continue to erupt and the alveolar processes grow. Direct ED-specific evidence comes from Kearns et al., in whose series one mandibular implant placed in a partially dentate five-year-old and four maxillary implants placed in a partially dentate seven-year-old became submerged as the adjacent alveolus developed and required longer abutments and prosthetic revision [16]. Ten-year follow-up of implants placed in adolescents without ED has likewise shown progressive infraposition of implant-supported crowns relative to adjacent teeth [11]. Infraposition is not limited to growing patients, however. Bernard et al. found vertical steps adjacent to anterior maxillary implants in adults aged 40 to 55 years that were similar to those in young adults [27], and Heij et al. noted that continued eruption of adjacent teeth remains a risk after 20 years of age in some facial types [28]. This is relevant for patients with ED who retain some natural teeth, and it qualifies the assumption that waiting for growth to finish eliminates the problem [16,27,28].

The anterior mandible has been the most frequently used and most predictable implant site in children with ED [7,18,24]. This is not because the region stops growing: Montanari et al. measured continued vertical growth of the symphysis below the implant apex and at the implant neck, together with sagittal growth, five years after loading in preteen patients, and their implants nevertheless performed well [18]. The stronger argument is that the changes in the anterior mandible are easier to manage, because transverse growth in this region is largely complete before the permanent canines erupt [24] and anodontic areas have no erupting neighboring teeth against which an implant could become infraoccluded. Concern has also been raised that rigid frameworks crossing the midline might restrict transverse growth, and some reports therefore divide the prosthesis at the midline or use a sliding bar such as that described by Montanari et al. [18,24]. However, Guckes et al. used bar-clip overdentures or fixed-detachable prostheses on anterior mandibular implants in a cohort that included children from eight years of age [7], and Kearns et al., who placed 19 maxillary implants in children and adolescents, found no sign that the implants or prostheses restricted transverse or sagittal growth [16]. The maxilla nevertheless remains the less predictable site in terms of survival [7,17,24]. Rather than applying a fixed chronological age threshold, clinicians should assess skeletal maturity and the anticipated pattern of growth [10], and long-term monitoring is essential whenever implants are placed in growing patients.

Conventional prosthetic treatment during growth

Removable prostheses remain an important component of treatment for children with ED. A removable complete or partial denture can restore mastication, speech, and esthetics as early as the preschool years and can be modified or remade as the child grows, while avoiding the potential complications of premature implant placement [3,4]. Schnabl et al. documented the broad range of prosthetic approaches used in HED, including removable dentures, overdentures over retained conical teeth, and implant-supported prostheses [3]. Children usually adapt well to removable prostheses, but frequent adjustment, relining, and replacement are required as the jaws grow, and retention may be poor on knife-edge ridges. Removable prostheses may therefore form part of a staged treatment plan, with selected mandibular implants added to improve the retention of an overdenture [18,20]. A staged approach for children is outlined in Figure *1*.

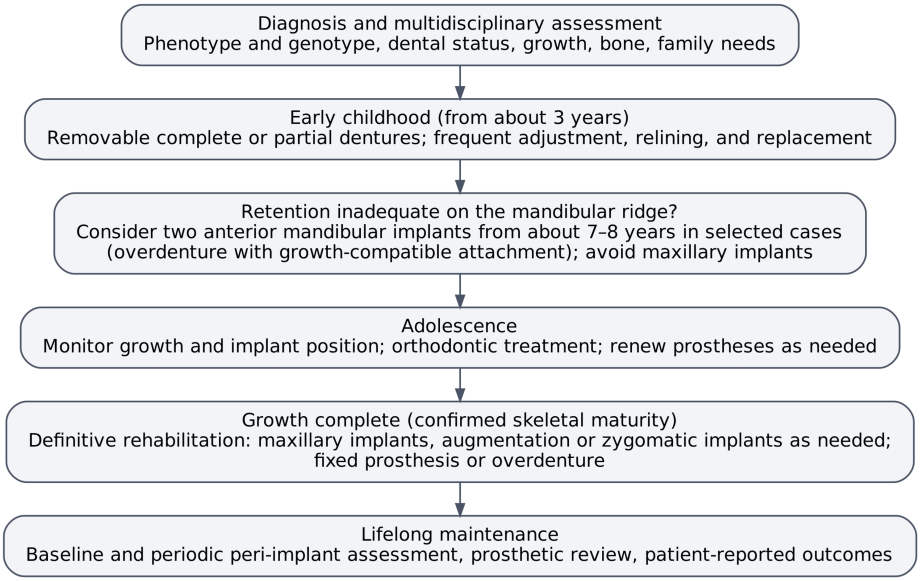


FIGURE 1: Staged approach to prosthetic and implant rehabilitation in children with ectodermal dysplasia

Ages are approximate and should be adapted to skeletal maturity and individual need

Bone availability and augmentation

Insufficient alveolar bone is one of the principal surgical challenges in patients with ED. The absence of permanent teeth results in reduced development of the alveolar ridge, particularly in areas of severe tooth agenesis, and preoperative assessment of bone height, width, and anatomical relationships is therefore essential. Three-dimensional imaging with cone-beam computed tomography is useful for evaluating potential implant sites, identifying anatomical limitations such as the position of the mandibular canal and the maxillary sinus, and determining whether augmentation is required.

Augmentation is common in this population: 68% of the adults in the review by Wang et al. underwent augmentation before implant placement [5]. Chrcanovic reported failure rates of 5.2% for implants placed in grafted bone (497 implants in 77 patients), 10.1% after distraction osteogenesis (79 implants in 16 patients), and 3.5% after Le Fort I osteotomy (99 implants in 20 patients) [6]. In patients with severe maxillary deficiency, zygomatic implants can avoid grafting altogether. Goker et al. placed 19 zygomatic implants in nine adults with ED aged 21 to 56 years, all of which survived over a mean follow-up of 55 months, with the prosthesis delivered on the day of surgery [12]. Narrower implants have also been used. Chrcanovic identified 33 mini-implants in the literature [6], Sfeir et al. used mini-implants in three children aged 11 to 12 years [29], and Zhu et al. reported good results with mini, narrow-diameter, and short implants in children, although implant size was not recorded for about half of the implants they analyzed [24]. These options are compared in Table *3*.

Approach	Typical indication	Reported outcomes and considerations
Autogenous bone grafting	Severe horizontal and vertical ridge deficiency	Implant failure 5.2% (497 implants, 77 patients)[6]; donor-site morbidity and additional surgical stages
Distraction osteogenesis	Marked vertical deficiency	Implant failure 10.1% (79 implants, 16 patients)[6]; longer treatment and need for patient cooperation
Le Fort I osteotomy	Maxillary deficiency with an unfavorable intermaxillary relationship	Implant failure 3.5% (99 implants, 20 patients)[6]; reserved for adults after completion of growth
Zygomatic implants	Severe maxillary atrophy in adults	Survival 100% (19 implants, nine adults; mean follow-up 55 months) [12]; avoids grafting but is surgically demanding
Mini-implants	Narrow ridges, particularly in children	33 mini-implants identified in the literature [6]; used in three children aged 11-12 years [29]
Short or narrow-diameter implants	Moderate deficiency, particularly in children	Good results reported in children, but implant size was not recorded for about half of the pooled implants [24]

TABLE 3: Augmentation and graft-avoiding approaches reported in patients with ectodermal dysplasia

Bone augmentation increases treatment complexity, duration, cost, and surgical morbidity, and repeated surgical procedures may be particularly burdensome for younger patients [3,5,6,24]. Consequently, augmentation should be planned as part of the overall prosthetic treatment plan rather than as an isolated surgical procedure. At present, there is insufficient ED-specific evidence to recommend any one augmentation technique as superior to another.

Prosthetic rehabilitation

The prosthetic component is a critical determinant of the long-term success of implant treatment. Depending on the number and distribution of implants, the available bone, and the functional and esthetic requirements, treatment may involve implant-retained overdentures or fixed implant-supported prostheses. Overdentures are particularly useful when the number of implants or the available bone is limited, because the denture flange can compensate for lost alveolar volume and lip support, and they are easier to modify during growth. Fixed implant-supported prostheses may be considered when sufficient implant support and favorable anatomical conditions are present, usually after growth has been completed [3,4].

Implant-supported prostheses improve retention and stability compared with conventional removable prostheses and may also improve mastication, speech, and esthetics [3-5]. However, prosthetic maintenance should be anticipated. Reported complications include screw loosening, prosthetic fracture, wear or loss of retention of attachment components, the need for relining, and the need for prosthetic adjustment [3,23,24]. In pediatric patients, the prosthesis may also require modification or replacement as the child grows [14,19].

Complications and long-term maintenance

Complications associated with implant therapy in ED can be broadly categorized as surgical, biological, prosthetic, and growth-related. The principal surgical challenge is often inadequate bone volume, and patients requiring extensive augmentation may undergo multiple surgical procedures [6]. Biological complications should be diagnosed according to the 2017 consensus definitions. Peri-implant mucositis is characterized by bleeding on gentle probing without bone loss beyond initial remodeling, whereas peri-implantitis additionally involves increased probing depth or recession and progressive bone loss. The same consensus report recommends obtaining baseline radiographs and probing measurements once the prosthesis has been completed, because later bone loss cannot be judged without a baseline [30]. ED-specific evidence on the incidence of peri-implant disease remains limited, although reduced salivary flow and difficulties with oral hygiene around overdenture attachments may increase the risk. Prosthetic complications, including screw loosening, prosthetic fracture, and relining, are common [3,22,24], and infraocclusion and positional discrepancies may develop even when the implant itself remains osseointegrated [11,16]. The main components of long-term follow-up are summarized in Table *4*.

Domain	Assessment
Baseline records	Radiographs and probing measurements once the prosthesis has been completed, as a reference for later assessment [30]
Implant and peri-implant tissues	Implant stability, probing depths, bleeding or suppuration on probing, and radiographic bone levels compared with baseline [30]
Oral hygiene and saliva	Plaque control around implants and attachments, and the management of xerostomia where present
Prosthesis	Integrity of components, screw stability, attachment retention, need for relining, and adjustment or replacement
Occlusion and implant position	Occlusal contacts, vertical position of implant restorations relative to adjacent teeth, and development of infraocclusion
Growth (pediatric patients)	Monitoring of craniofacial growth and timely prosthetic modification as the jaws develop
Patient-reported outcomes	Satisfaction, comfort, speech, chewing ability, and oral-health-related quality of life

TABLE 4: Components of long-term follow-up after implant therapy in patients with ectodermal dysplasia

Patient-reported and functional outcomes

The effects of ED extend well beyond the absence of teeth. Severe tooth agenesis can affect facial appearance, speech, mastication, self-confidence, and social interaction, and these effects are often apparent from early childhood [31]. In the largest survey of patient perceptions to date, Stanford et al. sent questionnaires to 253 people with ED, of whom 109 (43%) responded. Half of the respondents reported an implant or prosthetic complication and 24% reported some form of implant failure, yet 91% were satisfied or very satisfied with their implants, and 95% considered the treatment worth the time and cost [22]. Because satisfied patients may be more likely to respond, these figures may overestimate satisfaction, but they show that patients can value implant treatment highly even when complications occur [22]. Patient-reported outcomes have not, however, been measured consistently with validated instruments, and future studies should record oral-health-related quality of life, patient and parent satisfaction, speech, masticatory function, and psychosocial well-being before and after treatment.

Multidisciplinary management

Successful rehabilitation of patients with ED frequently requires a multidisciplinary approach. International consensus statements have recommended that care be coordinated by specialist teams with defined core standards of care and have emphasized the role of patient support groups in providing information and peer support to affected families [26,31]. Depending on the needs of the individual patient, the team may include the professionals listed in Table *5*. For children, treatment is best considered as a staged process in which removable prostheses restore function and esthetics while growth is monitored, a limited number of anterior mandibular implants may be placed in selected cases to stabilize an overdenture, and definitive rehabilitation of both jaws is deferred until growth is complete (Figure *1*) [18,24,26].

Team member	Principal role
Pediatric dentist	Early diagnosis, preventive care, and provision of interim removable prostheses in childhood
Prosthodontist	Prosthetically driven treatment planning, design of interim and definitive prostheses, and long-term maintenance
Oral and maxillofacial surgeon	Implant placement, bone augmentation, zygomatic implants, and orthognathic surgery when indicated
Orthodontist	Space management, alignment of existing teeth, and assessment of growth and skeletal maturity
Periodontist	Management of peri-implant soft tissues and prevention and treatment of peri-implant disease
Radiologist	Three-dimensional imaging of bone volume and anatomical relationships
Speech and language therapist	Assessment and management of speech difficulties related to tooth agenesis and prostheses
Psychologist	Support for self-esteem, social interaction, and adjustment to treatment for the patient and family
Clinical geneticist	Phenotypic and genetic diagnosis and family counseling
Other medical specialists	Management of systemic manifestations such as thermoregulatory, dermatological, and respiratory problems

TABLE 5: Members of the multidisciplinary team and their principal roles

Interpretation of the evidence

Two features of the evidence deserve emphasis beyond the findings already described. First, the systematic and critical reviews [5,6,15,23,24] draw on many of the same primary reports, including the cohorts of Guckes et al., Kearns et al., and Sweeney et al., so their agreement does not constitute independent confirmation. Second, the survival figures quoted in the literature are different measures: integration rates, crude survival, survival at a fixed time point, and Kaplan-Meier estimates extrapolated well beyond the mean follow-up. They should not be compared directly, and future studies should report each figure with its denominator, time point, and type of measure, together with implant-level and patient-level failure, prosthetic outcomes, patient-reported outcomes, and growth-related changes.

Limitations of the available evidence

The evidence on dental implant therapy in ED is limited by several factors. First, ED is rare, which makes large prospective studies difficult to conduct. Second, the condition encompasses multiple phenotypes, and the specific phenotype is often not reported. Third, published studies differ in implant systems, surgical techniques, prosthetic designs, patient ages, follow-up durations, and definitions of treatment success. Many studies are retrospective case series and case reports, which are susceptible to publication and survivorship bias [24], so the reported survival rates should not be regarded as applicable to all patients with ED. Finally, as a narrative review, this article did not apply formal risk-of-bias assessment or quantitative synthesis, and part of the literature was identified through reference lists rather than through the database search.

Future directions

Future research should focus on prospective, multicenter evaluation of patients with ED undergoing implant therapy, ideally through international registries that pool data from specialist centers [31]. Standardized reporting of outcomes, together with the specific ED phenotype and genotype [2], would facilitate comparison among studies. Digital treatment planning, computer-assisted implant surgery, and customized prosthetic workflows may also facilitate individualized treatment, although their benefits in ED require clinical evaluation. In the longer term, molecular therapy may change the clinical picture. Prenatal intra-amniotic administration of a recombinant EDA replacement protein restored sweating in male infants with X-linked HED [32], and follow-up of these boys for up to six years has shown that, in addition to being able to sweat, they had more permanent teeth than their untreated affected relatives [33]. A phase 2 trial of intra-amniotic ER004 (EDELIFE) is now under way [34]. The numbers remain very small, but the effect on the dentition, and hence on the future need for prosthetic and implant rehabilitation, is no longer entirely unknown.

Conclusions

Dental implant therapy can achieve favorable functional, esthetic, and prosthetic outcomes in appropriately selected patients with ED, but the evidence is limited, heterogeneous, and probably biased toward successful cases, and no universal treatment protocol exists. Treatment planning should take into account the ED phenotype, the severity and distribution of tooth agenesis, the available bone, and the prosthetic requirements. During growth, removable prostheses remain the foundation of treatment; when implants are needed in a growing patient, the anterior mandible is the most predictable site, and the patient and family should be informed that infraocclusion and prosthetic revision may follow despite successful osseointegration. Significant alveolar deficiency frequently requires augmentation, and graft-avoiding alternatives should be considered where appropriate. Implant survival should be evaluated separately from prosthetic success and patient-reported outcomes, and patients who receive implants, particularly children, require lifelong maintenance and monitoring within a multidisciplinary team.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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