Review

The use of mini-implants for provisional prosthetic rehabilitation in growing patients: a critical review

Marcos Cezar Pomini\textsuperscript{a,*}, Adriana Postiglione Buhrer Samra\textsuperscript{b}, Amanda Regina Fischborn\textsuperscript{b}, Vitoldo Antônio Kozlowski Junior\textsuperscript{b}, Fabiana Bucholdz Teixeira Alves\textsuperscript{b}

\textsuperscript{a} Department of Prosthodontics and Periodontics, Piracicaba Dental School, University of Campinas (Unicamp), Piracicaba, São Paulo, Brazil
\textsuperscript{b} Department of Dentistry, School of Dentistry, State University of Ponta Grossa (UEPG), Ponta Grossa, Paraná, Brazil

Abstract

Purpose: To critically review the literature using mini-implants for prosthetic rehabilitation of growing patients and to analyze the survival rates and clinical behavior of mini-implants.

Study Selection: Controlled clinical trials and case reports published in English, from January 2006 to October 2018, in a peer-reviewed journal in PubMed, Scopus, LILACS, and Cochrane Library databases. Studies using mini-implants for prosthetic rehabilitation in growing patients were included. Articles reporting mini-implants with a diameter greater than 3 mm, recruitment of adult participants, use of implants with other purposes than prosthodontic rehabilitation, and with a follow-up period shorter than 1 year, were excluded from the analysis. The selection was performed independently by two reviewers.

Results: The selection resulted in the inclusion of eight articles. Although the studies presented heterogeneous protocols and follow-ups (varying from 1 to 8 years), only one case of failure was reported, which corresponded to crown displacement. All rehabilitation procedures were performed in the anterior region using mini-implants with different diameters (1.3-2.9 mm) and lengths (9-14 mm). The prosthetic rehabilitation included individual crowns and/or overdentures.

Conclusions: Mini-implant prosthetic rehabilitation seems to be a viable and promising option for provisional rehabilitation of growing patients, since it seems to preserve the bone structure while restoring function and esthetics until growth ceases, when then mini-implants can be replaced by standard implants.

Keywords: Dental implants, Growth, Child

Received 19 Jun 2019, Accepted 28 April 2020, Available online

1. Introduction

Traumatic injuries affect approximately 22.7% of the child population worldwide. It is estimated that 180 million children have had at least one traumatic dental injury, which is one of the leading reasons for tooth loss in growing patients\textsuperscript{[1]}. In addition, agenesis of second premolars, maxillary lateral incisors and mandibular incisors is also a frequent reason for tooth loss\textsuperscript{[2]}. Among the most common causes of agenesis are congenital hypodontia/anodontia, which can be related to syndromes such as ectodermal dysplasia (ED)\textsuperscript{[2-3,4]}. Prosthodontic rehabilitation in growing patients (children and adolescents) is routinely performed in clinical practice, mostly before school enrollment to minimize nutrition, speech and esthetic impairments\textsuperscript{[4]}

Missing teeth can be replaced through different approaches. The rehabilitation with removable prosthetic devices has been the treatment of choice for growing patients, even though the literature suggests that it may increase residual alveolar resorption, dental caries incidence, and periodontal complications, as well as it relies considerably on the child’s compliance\textsuperscript{[2,3]}. Among the most common causes of agenesis are congenital hypodontia/anodontia, which can be related to syndromes such as ectodermal dysplasia (ED)\textsuperscript{[2-3,4]}. Prosthodontic rehabilitation in growing patients (children and adolescents) is routinely performed in clinical practice, mostly before school enrollment to minimize nutrition, speech and esthetic impairments\textsuperscript{[4]}

Missing teeth can be replaced through different approaches. The rehabilitation with removable prosthetic devices has been the treatment of choice for growing patients, even though the literature suggests that it may increase residual alveolar resorption, dental caries incidence, and periodontal complications, as well as it relies considerably on the child’s compliance\textsuperscript{[2,3]}. Among the most common causes of agenesis are congenital hypodontia/anodontia, which can be related to syndromes such as ectodermal dysplasia (ED)\textsuperscript{[2-3,4]}. Prosthodontic rehabilitation in growing patients (children and adolescents) is routinely performed in clinical practice, mostly before school enrollment to minimize nutrition, speech and esthetic impairments\textsuperscript{[4]}

Nonetheless, the use of implants in growing patients must be evaluated carefully as their dentition and jaws are undergoing a period of active, dynamic development\textsuperscript{[3]}. Standard implants (SI) are expected to be covered by alveolar growth, ending up in infra-position\textsuperscript{[5]}. Oesterle et al.\textsuperscript{[7]} compared osseointegrated implants in children with ankylosis of primary teeth, whom have restricted alveolar growth...
and tooth eruption. The authors pointed out that implants placed in the posterior maxilla of these patients have the risk to be exposed in the nasal and antral floor as their maxillae develop[7]. Hence, it has been recommended to wait for the completion of dental and cranial growth prior installing a dental implant[3]. To date, conventional implant placement in growing patients remains a controversial issue that requires a careful diagnosis and treatment plan. Nonetheless, mini-implants (MI), commonly used for orthodontic anchorage, have been used for prosthetic rehabilitation of edentulous growing and adult patients[5,8]. The Glossary of Oral and Maxillo-Facial Surgery considers MI as those with a diameter threshold of 3 mm[8]. Although MI and SI are both considered dental implants, MI present a substantially smaller surface area and roughness, which decreases osseointegration by several hundred percent, making it highly unlikely to osseointegrate[9]. This key concept, together with the fact that MI significantly improve the masticatory efficiency, speech and comfort, as compared to conventional dentures[10,11], led authors to use MI for transitional rehabilitation of growing patients[9]. Additionally, MI have a lower cost than SI and require simplified placement procedures, since most of them are placed by means of a flapless surgical procedure and are designed as a single-piece device to be used in narrow ridges[8].

Nevertheless, the literature has pointed out a lack of mid- and long-term in vivo evidence-based studies to support the use of MI for prosthetic purposes[8]. Even though several authors have performed MI rehabilitations with positive outcomes over time[5,9,12], the controversial opinions on the use of implants during cranial growth[3] and on MI osseointegration[13,14] are the main limitations of this novel protocol for growing patients. Thus, the aim of this study was to review the current literature of clinical trials and case reports using MI for prosthetic rehabilitation of growing patients (children and adolescents) and to analyze the short-, mid-, and long-term survival rates and clinical behavior of MI. The hypothesis tested was that MI prosthetic rehabilitation is a safe promising technique for growing patients.

2. Material and Methods

This review was limited to the studies retrieved from the electronic searches. Manual searching of printed articles and conference proceedings were outside of our scope. An independent electronic search of clinical trials and case reports was carried out by two examiners (M.C.P. and F.B.T.A.) in the PubMed, Scopus, LILACS, and Cochrane Library databases. The review considered articles published from January 2006 to October 2018. The following descriptors were used in the searches: “Dental implants” [MeSH] AND “Growth” [MeSH] AND “Child” [MeSH]. The exact term “dental implants” was used to cover the terms “mini-implants”, “interim implants”, “microimplants,” “miniplate”, “narrow diameter implants”, and “transitional implants”, since there is no agreement regarding the exact terminology associated with small implants[8]. To be included in this review, the articles had to meet the following eligibility criteria: 1) any clinical trial or case report published in English in a peer-reviewed journal; 2) studies investigating the clinical use of MI for prosthetic reasons in growing patients. The exclusion criteria were as follows: 1) studies that considered MI those with a diameter threshold greater than 3 mm; 2) studies that recruited adult participants (18 years or older); 3) articles that described the use of MI for other purposes than prosthetic rehabilitation; 4) studies with a follow-up period shorter than 1 year; 5) studies that did not report length or diameter of the MI; and 6) patients that were repeatedly reported in other included articles.

The electronic searches were performed in four steps. First, the article titles were analyzed by two examiners based on the eligibility criteria. All selected articles were managed with the aid of the software State of the Art through Systematic Review - StArt (version 3.0.3, LaPES, UFSCar, São Carlos, SP, Brazil). Second, the abstracts from the selected articles were screened for eligibility, and the exclusion criteria were applied. Third, relevant abstracts were selected for full-text analysis. Lastly, the list of bibliographical references in the selected articles was manually checked to identify additional articles that could be potentially eligible for the review. The exclusion criteria were reapplied to all selected articles and the studies were reviewed for data extraction. The following characteristics were extracted: author/year, summary of the case(s) (patient information/diagnosis, treatment, surgical technique, and type of implant), clinical longevity of the MI, shortcomings, and clinical outcomes. In all steps, the articles were analyzed independently by the two examiners and any conflicting decision was resolved by reanalyzing the article(s) until a consensus was achieved. For the purpose of this review, we considered short-, mid- and long-term survival of MI one year, two to six years, six years or more after placement and function, respectively. Clinical success was considered as esthetic and functional implant prosthetic rehabilitation, with healthy implant beds and absence of alveolar resorption, as well as absence of interference in the maxillary and mandibular vertical, sagittal, and cross-sectional bone development.

3. Results

A summary of selection procedures, findings and reasons for exclusion are shown in a flow diagram (Figure 1). The electronic searches resulted in a total of 187 articles, of which 84 abstracts were identified as potential studies for inclusion. Further screening of abstracts and removal of repeated articles resulted in the selection of 13 articles for full-text analysis. Manual searches in the reference lists of selected articles resulted in the inclusion of one additional article, totaling a selection of 14 articles for full-text analysis. Of these, eight articles met the inclusion criteria and were included in the final review. The main reasons for exclusion were as follows: implant with a diameter greater than 3 mm[15,16], follow-up period shorter than 1 year[11,17], patient older than 18 years[18], and MI diameter or length not reported[19]. All the eight studies had a prospective methodological design, with the largest sample size consisting of three patients and the smallest, one (Table 1). The patients’ ages ranged from 4 to 15 years, with an average of 11 years. Maxillary and/or mandibular individual crowns were used in seven studies, while mandibular implant-supported overdentures were used in two studies. Three studies were performed in South America, two in Asia, two in Europe, and one in North America.

As shown in Table 1, most of the rehabilitation procedures were performed using MI with different diameters (1.3-2.9 mm) and lengths (9-14 mm), as well as using different prosthetic components. Positive clinical outcomes were reported in seven of the eight studies. The survival rates of MI were evaluated in different times and ranged from a minimum follow-up of one year to a maximum of eight years. The points raised to justify clinical success were mainly the presence of a functional and esthetic prostheses and the absence of bone resorption in the last follow-up, as well as no interference in maxillary and mandibular bone development. In contrast, the study by Jofré and Werner [14] reported a failure of the rehabilitation procedure due to infra-occlusion and lack of crown retention on the abutment head, which resulted six times in the loss of the acrylic-resin crown. After six years, the authors decided to remove the MI, which presented high resistance due to osseointegration. It is important to note that, although considering it a case of success, Gianetti et al. [20] reported the presence of minimal infra-occlusion (< 0.5 mm) after 24 months, which was functionally and esthetically corrected with the prosthetic device.

In the selected articles, all studies investigated the clinical use of MI placed in the anterior region of the maxilla[5,9,13,14,20], mandible[21,22], or both[12]. Likewise, with the exception of Jofré and Werner[14] and Gianetti et al.,[20] no other study found any
Electronic searches
N=187 articles for 'Dental implants' AND 'Child' AND 'Growth'

Exclusion criteria applied
N=71 articles excluded

Independently selected by two examiners
N=84 abstracts identified

N=13 full articles selected

Discussion
N=13 full text analysis

N=14 articles for full text analysis

Final number of articles included
N=8

Exclusion criteria applied
N=3, implant diameter greater than 3 mm
N=1, follow-up time too short
N=1, patient older than 18 years
N=1, length or diameter not reported

Fig. 1. Flow diagram of the search strategy and selection of articles to be included in the systematic review.

Table 1. Studies assessing mini-implants for prosthetic rehabilitation of growing patients.

| Authors            | Study design | Patient age (years) | Site of placement | Diameter / length (mm) | Type of prosthetic component       | Follow-up time (years) | Clinical outcome | Complications                  |
|--------------------|--------------|---------------------|-------------------|------------------------|-----------------------------------|------------------------|-----------------|------------------------------|
| Giannetti et al.   | Prospective  | 10                  | Anterior maxilla  | 2.5 / 13               | Resin-metal crown               | 2                      | Positive        | Minimal infraocclusion (<0.5mm) corrected with the prosthesis |
| Cope and McFadden  | Prospective  | 12                  | Anterior maxilla  | 2.2 / ND               | Ceramic crown                   | 8                      | Positive        | Provisional crown replaced after 12 months due to discoloration |
|                    |              |                     |                   |                        |                                   |                        |                 | None reported                  |
|                    |              |                     |                   |                        |                                   |                        |                 | None reported                  |
| Sfeir et al.       | Prospective  | 11                  | Anterior mandible | 1.8 / 13               | Fixed-detachable denture         | 2                      | Positive        | None reported                  |
|                    |              |                     | and maxilla       |                        |                                   |                        |                 | None reported                  |
|                    |              |                     |                   |                        |                                   |                        |                 | None reported                  |
|                    |              |                     |                   |                        |                                   |                        |                 | None reported                  |
| Wilmes et al.      | Prospective  | 14                  | Anterior maxilla  | 2.0 / 11               | Acrylic-resin crowns            | 6                      | Positive        | None reported                  |
| Costa et al.       | Prospective  | 13                  | Anterior maxilla  | 2.0 / 11               | Acrylic-resin crown             | 5                      | Positive        | None reported                  |
| Sofre and Werner   | Prospective  | 10                  | Anterior maxilla  | 1.8 / 14               | Acrylic-resin crown             | 6                      | Negative        | High frequency of provisional crown loss and high forces needed to remove the MI after 6 years |
| Kilic et al.       | Prospective  | 6                   | Anterior mandible | 2.9 / 13               | Fixed-detachable denture        | 6                      | Positive        | None reported                  |
| Oliveira et al.    | Prospective  | 10                  | Anterior maxilla  | 1.6 / 10               | Acrylic-resin crown             | 1                      | Positive        | None reported                  |

ND: not described

changes in the vertical position of the implant-supported prosthesis. All other authors concluded that the follow-up of MI demonstrated not only absence of local bone growth inhibition, but also the presence of healthy implant beds. In fact, Cope et al. [9] even reported 1.2 mm of bone growth coronally along the threads of the MI. These optimal outcomes resulted in the choice of Wilmes et al. [5] to only replace the crown when bone growth was complete, thereby preserving the MI. No article reported replacement of the MI for standard implants when the growth was completed on the grounds that implant stability had been achieved.

Nevertheless, prosthetic replacement was performed several times in all cases, mainly due to bone growth. Most studies initially rehabilitated patients with a temporary acrylic resin[5,13,14,20,21], polycarbonate[9], or composite crowns[12]. However, not all authors replaced the temporary crowns for wear-resistant materials. Instead, some authors only performed the substitution of the crown for another one of the same material[5,13,14], with no information regarding the timeframe at which they were replaced[5,13]. Costa et al. [21] initially
rehabilitated with an acrylic resin crown, which remained in function for one year. Among the cases in which the prosthetic components were replaced, the main materials opted were porcelain[9,12], resin-metal[20], or metal ceramic crowns[12]. The timeframe at which these crowns were replaced ranged from 3 months[20] to 4 years[12], with the majority of them being replaced within one year of clinical use (3 [20] and 9 months [9]). Additionally, Killic et al. [22] installed mandibular overdentures, with complete replacement in 15, 60 and 72 months.

The selected articles showed differences in terms of surgical technique and immediate loading of the implants. Most authors reported immediate prosthetic load on the implants [5,12,13,14]. However, Gianetti et al. [20] opted for prosthetic load after 12 hours, while Killic et al. [22] waited four months. Costa et al. [21] rehabilitated patients with a resin crown in infra-occlusion, which remained as such during the follow-ups of 1, 6, and 12 months. Similarly, Cope et al. [9] installed temporary crowns free of functional and excursive contacts, which were later (6 and 12 months) replaced by functional crowns. As for the surgical procedures, two authors [9,20] reported the use of full thickness soft tissue flap for implant placement, claiming a better view of the operatory field, while Jofré et al. [14] and Oliveira et al. [13] opted for flapless surgery.

4. Discussion

The goal of MI prosthetic rehabilitation in growing patients is to improve esthetics, comfort and stabilize bone ridges until skeletal growth is complete, when then standard implants should be placed[9]. The present review analyzed the clinical behavior and survival rates of MI in these patients. Nevertheless, due to limited evidence, conflicting terminology, and heterogeneous protocols and follow-ups, only general considerations can be drawn from the analysis of selected articles. It is worth mentioning that even though MI have been used for more than 15 years[8], the current evidence corresponds mostly to case reports.

Despite these limitations, the present review highlights important information concerning the use of MI in growing patients, focused particularly on their indication for prosthetic rehabilitation.

The benefits of implant placement in growing patients are as important as the concern for premature placement of implants. The literature advocates that SI should not be placed in growing patients before their growth ceases, with the exception of the anterior maxilla[23]. Likewise, the use of MI in the anterior mandible in cases of ectodermal dysplasia has been univocal in the literature[12]; however, there is a lack of scientific evidence for their placement in the posterior region of growing patients [5]. Therefore, we advise increased caution placing MI in this region. Since implant placement creates an anklyotic response, the compensatory tooth eruption promoted by the rotational growth pattern of the maxilla and mandible is expected to alter implant and jaw positions, thereby resulting in prosthetic infra-occlusion, particularly in partially edentulous patients[19,20,23]. In addition, the sutural growth of the maxillae ends during early adulthood, hence conventional implant placement in a growing maxilla before that is expected to restrict transversal growth[3]. On the other hand, transversal growth of the anterior mandibular region is minimal after the six months of life[19]. Therefore, the rehabilitation with overdentures supported by implants placed in the anterior region is a favorable option and does not overload individual implants[23], which is in line with the report by Seifr [12], included in the present review, and Toomarian [19]. Of note, rigid connections crossing the midline must be avoided in order to allow the mandible to widen[23].

In this sense, age-related problems in terms of placing implants in growing arches must be considered. Since age is related to alveolar bone growth, the fact that the patients in this review showed minimal or no complications in the anterior regions[5,9,12,21] shows that the behavior of MI rehabilitations regarding site of placement might be different than conventional ones, highlighting the importance of new investigations on the topic. This controversial long-term behavior accentuates that follow-ups must be more frequent in younger patients and occlusal contacts must be frequently reassessed[5,9,12] in order to prevent occlusal interferences and overloading the mini-implant[5].

In addition, a longer use of MI is indicated in younger patients, although this point has not been addressed in the selected studies. To date, the clinical consequences of the prolonged use of MI remain elusive.

While there is a consensus in the scientific literature regarding the use of implants in growing patients, the use of MI is still controversial. With the possibility of being used in thin ridges and limited interradicular spaces[24] as well as relying on bone-implant contact – which allows them to be removed at a later date, MI may help preserve the crestal and buccolingual alveolar bone and surrounding soft tissues and thereby could function as a transient rehabilitation procedure for growing patients[9]. Given this, MI have been installed in sites where the use of SI is contraindicated[24], such as in the growing maxilla. Six [5,9,12,13,14,20] of the eight cases in the present review reported rehabilitation with MI in the anterior maxilla, with up to 8 years of follow up, with failure reported in only one case[14]. It is worth mentioning that the failure stated by Jofré and Werner [14] was related to provisional crown displacement due to lack of retention on the implant surface. In this regard, MI may submerge relative to the adjacent teeth[9], so the surface area available for crown retention may become insufficient. On the other hand, the stated success of the MI rehabilitation resulted in the preservation of the MI when the growth ceased[5].

Although prosthetic rehabilitation with MI seems promising, it should be reassessed when the patient’s growth ceases in that replacement for SI should be performed due to several reasons, namely: individual MI placement to restore teeth under higher occlusal forces is expected to increase mechanical complications[24]; upon clinical use, MI tend to present surface degradation and plastic deformation[25]; rehabilitation with MI has also been reported to increase the tendency of fracture (since a lower amount of load is necessary to fracture smaller diameter implants) and crestal bone loss due to stress concentration[24]; lastly, the use of 2-piece implants, such as conventional implants, allows the correction of the emergence profile and crown angulation, which is critical in MI[24].

Another practical consideration for clinicians is the degree to which MI rely on osseointegration. Complete osseointegration might be undesirable since MI should be replaced when the growth ceases. However, the literature regarding the osseointegration of MI is still inconclusive[14,26]. As the removal torque is proportional to the screw radius and bone contact area, much less torque is expected to remove a MI[27]. Motoyoshi et al.[28] stated that removal torques of MI averaged around 8 and 4 Ncm, which can be easily removed with a screwdriver and a small torque wrench. However, in the present review, Jofré and Werner [14] applied high level of forces (50 Ncm) to remove a 6-year provisional MI. The authors stated the presence of vertical discrepancy between the implant and the adjacent teeth (infra-occlusion), cutting off loading on the MI, which has been related to increased osseointegration[27]. It should be noted that the total surface area and surface roughness of MI also play an important role in the osseointegration dynamics[5,9]; thus, decreased diameter and the smooth and polished surface are more related to osseointegration than MI length[5,9]. Therefore, the improvement of the MI design for prosthetic treatment[8,29], such as surface treatment, could favor osseointegration, resulting in some studies observing similar osseointegration between MI and standard implants[26].

This review also addressed the role of MI design on the stability and bone stress. The selected articles reported different implant diameters and lengths, varying from 1.3 to 2.9 mm and 9 to 14 mm, respectively, with all the MI placed in the anterior maxilla or mandible. The literature has pointed that the MI intrabony length does not affect stability. On the contrary, MI with larger core diameters seem to be
more stable than those with larger thread depth[33]. In view of this, it has been suggested that a MI for a growing patient should be large enough for stability but small enough to allow bone growth[5]. In fact, rather than implant design, stability has been more related to bone cortical thickness and quality. Most of the stress during function is transmitted to the cortical bone layer on the side of compression[33], meaning that bones with higher density, such as anterior mandible and maxilla, are more stable than the posterior regions - this explains the high level of success in the included cases. It is worth mentioning that none of the cases evaluated MI placement in the posterior maxilla, a lower bone density area. This reinforces the need for further longitudinal clinical and histomorphometric evaluations distinguishing MI prosthetic stability in different areas of the maxilla and mandible.

Although osseointegration is not desirable, some coronal bone growth might be expected, yet, it could be considered positive since it shows that even if the ankylotic response occurs, the nearby tissues should develop normally. If the coronal bone growth impairs the prosthetic rehabilitation, the MI may be backed out or the prosthesis may be complemented additively to maintain the maxilla-mandible relationship[9]. In addition, there are versatility of MI coronal designs that have the ability to receive standard abutments [9], including the use of MI with an inner thread, which allows the clinician to attach the abutment to the crown with a small fixation screw[5]. Despite that, even when osseointegration occurs, the resulting cavity upon removal of the MI will be considerably smaller than the pilot cavity for a definitive implant[9]. Osseointegration around MI should be evaluated carefully since its consequences on MI removal are uncertain, which may include vertical and horizontal bone defects and possible alterations of the emergence profile. It has to be considered that periodic follow-ups are mandatory, so if there is any negative alteration, it should be minimal and easy to be corrected.

Follow-up of MI prosthetic rehabilitation in growing patients should be addressed differently than in adults and according to each case (individual or multiples absences, patient’s age, occlusal forces, and MI site). While the follow-up period of standard implants varies between 3 and 12 months[11], MI should be followed up for longer periods due to several reasons. First, based on the functional matrix theory developed by Moss (craniofacial growth is mainly affected by function)[30], implant-prosthesis must transfer functional loads onto the alveolar process where growth has stopped because of the absence of the tooth, allowing the bone to remodel[20,31]. In addition, the literature advocates that immediate loading of MI does not raise any concern[32]. Therefore, due to the tendency of infra-occlusion of implant placement in growing patients, prosthetic care in growing patients should be as carefully assessed as the implant care itself, with frequent replacements following bone development and occlusal changes to maintain the occlusal plane[3]. In fact, it might have to be heightened if MI is not restored with wear-resistant materials, such as temporary acrylic resin crowns. In this review, all cases reports replaced the prosthetic components; however, two studies[9,21] rehabilitated the patients in infra-occlusion, which might pose an increased risk for future complications. Overall, there is no evidence on the most appropriate timeframe and intervals between the follow-ups, but the literature in this review indicates that a 3-month interval period is effective for monitoring MI until skeletal growth is complete[13,20], when then the use of MI must be reassessed.

Taken altogether, the present review should be interpreted with caution due to the variability of the cases included. Longitudinal evidence on long-term behavior and efficacy of MI is lacking and further studies are needed to demonstrate their potential for use in growing patients[25], especially as a definitive component, although the authors have suggested that rehabilitation with MI should not be extended. Herein, we reported many parameters that were not evaluated in the selected case reports, which open further avenues for future research. Finally, the use of MI seems to be a reliable option for transitional prosthetic rehabilitation in growing patients for specific cases and promising enough to rise great interest in further studies to enlighten more embracing clinical situations.

5. Conclusion

Within the limitations of this critical review, the following conclusions can be drawn:

1. Although limited, clinical evidence on the survival rates of mini-implants for prosthetic rehabilitation in growing patients is encouraging, with successful follow-ups up to eight years.

2. The use of mini-implants for provisional prosthetic rehabilitation in child and adolescents preserves the bone tissues while restoring functional and esthetical parameters. Nevertheless, mini-implants should be replaced by standard implants when the bone growth is complete.

Conflicts of interest

The authors declare that they have no conflicts of interest.

References

[1] Richards D. One billion people have experienced a traumatic dental injury. Evid Based Dent 2018;19:34-5. https://doi.org/10.1038/ejebd.6401297.

[2] Agarwal N, Kumar D, Anand A, Bhatwar SK. Dental implants in children: A multidisciplinary perspective for long-term success. Nat J Maxillofac Surg 2016;7:122-6. https://doi.org/10.4103/0975-5950.203362.

[3] Gobbi P, Choudhary R, Puppli FA, Naganar E, Madali P. Osseointegrated dental implants in growing children: a literature review. J Oral Implantol 2014;40:627-31. https://doi.org/10.1563/AAID-JOI-D-11-00186.

[4] Schnabl D, Grunert I, Schmitt M, Kapferer-Soehbener I. Prosthetic rehabilitation of patients with hypohidrotic ectodermal dysplasia: A systematic review. J Oral Rehabil 2018;45:555-70. https://doi.org/10.1111/oor.12638.

[5] Wilmes B, Nienkemper M, Renger S, Drescher D. Mini-implant-supported temporary pontics. J Clin Orthod 2014;48:422-9.

[6] Mishra SK, Choudhary N, Choudhary R. Dental implants in growing children. J Indian Soc Pedod Prev Dent 2013;31:3-9. https://doi.org/10.4103/0970-4388.112292.

[7] Oesterle LJ, Cronin RJ Jr, Raify DM. Maxillary implants and the growing patient. Int J Oral Maxillofac Implants 1998;3:377-87.

[8] Bidra AS, Almas K. Mini implants for definitive prostodontic treatment: a systematic review. J Prosthodont 2013;109:156-64. https://doi.org/10.1563/0003-7850.1360035-9.

[9] Cope JB, McFadden D. Temporary replacement of missing maxillary lateral incisors with orthodontic miniscrew implants in growing patients: rationale, clinical technique, and long-term results J Orthod. 2014;41:662-74. https://doi.org/10.1179/1465531314Y.0000000012.

[10] Preoteasa E, Marin M, Imre M, Lerner H, Preoteasa CT. Patients' satisfaction with conventional dentures and mini implant anchored overdentures. Rev Med Chir Soc Med Nat Iasi 2012;116:310-6.

[11] Mello BZF, Silva TC, Rios D, Machado MAAM, Valarelli FP, Oliveira TM. Mini-implants: Alternative for Oral Rehabilitation of a Child with Ectodermal Dysplasia. Braz Dent J 2015;26:75-8. https://doi.org/10.15840/0100-6460201500111.

[12] Sfer E, Nassif N, Moukarzel C. Use of mini dental implants in ectodermal dysplasia children: follow-up of three cases. Eur J Paediatr Dent 2014;15:207-12.

[13] Oliveira NS, Barbosa GLB, Lanza LD, Pretti H. Prosthetic Rehabilitation of Child Victim of Avulsion of Anterior Teeth with Orthodontic Mini-Implant. Case Rep Dent 2017;8:909565. https://doi.org/10.1159/2017.8909565.

[14] Jofré J, Werner A. Use of mini implants to replace a missing tooth in a growing patient: a six-year follow up case report. Eur J Paediatr Dent 2015;16:284-6.

[15] Gölner P, Jung BA, Wehrbein H, Liechti T. New method of temporary prosthodontic rehabilitation after traumatic tooth loss in a juvenile patient: a case report. Dent Traumatol 2009;25:238-41. https://doi.org/10.1111/j.1600-9657.2008.00740.x.

[16] Huang PY, Driscoll CF. From childhood to adulthood: oral rehabilitation of a patient with ectodermal dysplasia. J Prosthodont 2014;13:439-43. https://doi.org/10.1016/j.prosdent.2014.04.012.

[17] Artopoulos II, Martin JW, Suchko GD. Prosthodontic rehabilitation of a 10-year-old ectodermal dysplasia patient using provisional implants. Pediatr Dent 2009;31:52-7.

[18] Mascolo A, Boschetti E, Flanagan D. An ectodermal dysplasia patient treated with a small diameter implant supporting a single crown. Clin Cosmet Investig Dent 2018;10:171-7. https://doi.org/10.2147/CCIDE.S170670.
Toomarian L, Ardakani MR, Ramezani J, Adli AR, Tabari ZA. Using implants for prosthodontic rehabilitation of a 4-year-old with ectodermal dysplasia. Gen Dent 2014;62:1-5.

Giannetti L, Murri Dello Diago A, Vecchi F, Consolo U. Mini-implants in growing patients: a case report. Pediatr Dent 2010;32:239-44.

da Costa MG, Melgaço CA, Corrêa-Faria P, Marques LS. Functional and Esthetic Treatment of Lateral Incisor Agenesis with a Mini-Implant in a Young Patient: A Case Report. Int J Orthod Milwaukee 2015;26:55-7.

Kelic S, Altintas SH, Yilmaz Altintas N, Ozkaynak O, Bayram M, Kusgoz A, et al. Six-Year Survival of a Mini Dental Implant-Retained Overdenture in a Child with Ectodermal Dysplasia. J Prosthodont 2017;26:70-4. https://doi.org/10.1111/jopr.12366.

Bryant SR. The effects of age, jaw site, and bone condition on oral implant outcomes. Int J Prosthodont 1999;11:470-90.

Imam AY, Moshaverinia A, McGlumphy EA. Implant-abutment interface: a comparison of the ultimate force to failure among narrow-diameter implant systems. J Prostheth Dent 2014;112:136-42. https://doi.org/10.1016/j.prosdent.2014.01.020.

Marigo G, Elias CN, Marigo M. Surface analysis of 2 orthodontic mini-implants after clinical use. Am J Orthod Dentofacial Orthop 2016;150:89-97. https://doi.org/10.1016/j.ajodo.2015.12.012.

Dhaliwal JS, Albuquerque RF Jr, Mundle M, Feine JS. Osseointegration of standard and mini dental implants: a histomorphometric comparison. Int J Implant Dent 2017;3:15. https://doi.org/10.1186/s40729-017-0079-1.

Kim SH, Cho JH, Chung KR, Kook YA, Nelson G. Removal torque values of surface-treated mini-implants after loading. Am J Orthod Dentofacial Orthop 2008;134:36-43. https://doi.org/10.1016/j.ajodo.2006.07.038.

Kusgoz A, Skirbutis G, Harb A, Barzdziukaitė I, Grinytė I. New approach towards mini dental implants and small-diameter implants: an option for long-term prostheses. Stomatologija 2012;14:39-45.

Moss ML. The functional matrix hypothesis revisited. 3. The genomic thesis. Am J Orthod Dentofacial Orthop 1997;112:338-42.

Ciarmatori E, Passaretti A, Micacolo G, Cicconetti A. Critical review of literature on the use of short implants. J Osseointegr 2018;10:87-94. https://doi.org/10.23805/jo.2018.10.03.04.

Preoteasa E, Meleșcanu-Imre M, Preoteasa CT, Marin M, Lerner H. Aspects of oral morphology as decision factors in mini-implant supported overdenture. Rom J Morphol Embryol 2010;51:309-14.

Duabibis R, Kusnoth B, Natarrjan R, Zhao L, Evans C. Factors affecting stresses in cortical bone around miniscrew implants: a three-dimensional finite element study. Angle Orthod 2010;82:875-80. https://doi.org/10.2319/111011-696-1.