Infraocclusion level and root resorption of the primary molar in second premolar agenesis: A retrospective cross-sectional study in the Portuguese population

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Abstract

Background. Mandibular second premolar (M2P) agenesis results in the second primary molar (2pm) retention, infraocclusion, a reduced alveolar height and width, the supraeruption of antagonists, or the movement of the adjacent teeth. Infraocclusion affects the survival of the retained 2pm to a greater extent than root resorption.

Objectives. The aim of the study was to evaluate the lifespan of the primary molar as a substitute, with root quality and occlusal adaptation, in cases of M2P agenesis in a low-income population to determine if the attitude of just vigilance could be the best clinical option whenever other clinical problems are absent.

Material and methods. A total of 12,949 orthopantomograms were analyzed. Sixty-one patients (25 males and 36 females aged 7–36 years) were divided into group 1 (the first permanent molar in occlusion) and group 2 (the second permanent molar also in occlusion). Vertical positioning to the occlusal plane, root condition and the movement of the adjacent teeth were evaluated.

Results. Despite the study having a cross-sectional design, root resorption, infraocclusion, the distance between the first permanent molar and the first primary molar or the first permanent premolar, and the width of the 2pm were correlated with age. The 2pm root resorption increased with age, which was more pronounced when the second permanent molar was also in occlusion. The mesial movement of the adjacent teeth was absent in all groups. The 2pm was often occluded, but infraocclusion increased with age. Age periods of 11–15 years and 21–25 years were critical for the primary tooth loss.

Conclusions. The second primary molar remains functional in the mandibular arch for up to 25 years. A well-documented no-intervention attitude based on clinical and radiographic data must be weighed in cases without orthodontic issues or with financial constraints.

Keywords: root resorption, infraocclusion, second primary molar, second premolar agenesis, mesial movement

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Introduction

Dental agenesis occurs in primary and permanent dentition, usually in the case of third molars, mandibular second premolars, maxillary lateral incisors, and maxillary second premolars,[1–3] as a sporadic, spontaneous de novo mutation[4] or as familial hypodontia, mainly due to autosomal dominant inheritance,[5] but also as part of a syndromic condition,[6] as a phenotypic feature of common conditions, such as Down syndrome or ectodermal dysplasia,[7,8] isolated or as part of complex syndromes, like labiopalatal cleft[8,9] or oral-facial-digital syndrome type I.[7,10]

Other causative factors are environmental factors (radiotherapy, chemotherapy, the disease or infection of the primary tooth, tobacco consumption) or host factors (a viral infection during pregnancy, metabolic imbalance).[11,12]

Different genes are linked with tooth agenesis, including *AXIN2*, *IRF6*, *FGFR1*, *MSX1*, *PAX9*, and *TGFA*.[13,14] To date, several single-nucleotide polymorphisms (SNPs) and mutations influencing the function of *AXIN2* have been identified and related to both tooth agenesis and colorectal or hepatocellular carcinoma, or prostate, ovary or lung cancer. This supports the hypothesis that missing teeth can be a marker for predisposition to cancer.[9,13] Agenesis can be diagnosed early in life, allowing the implementation of surveillance programs,[15,16] as in the case of the demonstrated positive correlation in a three-generation family with an *AXIN2* variant and a history of colorectal cancer, colon polyps and tooth agenesis, probably more as an associated event than as a causative one.[17]

The prevalence and severity of dental anomalies are high in humans, and seem jaw- and location-dependent, as most dental anomalies in the maxilla involve the anterior region, and in contrast, the opposite occurs in the mandible, which can be possibly explained by different evolutionary history and ontogeny.[18] Non-syndromic orofacial clefts are frequently associated with tooth abnormalities other than agenesis, such as supernumerary teeth, developmental enamel defects, microdontia, peg-shaped anterior teeth, taurodontism, tooth malposition and/or transposition, tooth rotation, or tooth impaction, but no association with fusion and/or germination has been observed.[19]

There is evidence of an association between the nutritional status, specifically vitamin D and calcium levels, and severe early childhood caries (S-ECC) in preschool children.[20] Still, in severe vitamin D deficiency, there is a high risk of non-syndromic amelogenesis imperfecta and dentinogenesis imperfecta, enamel hypoplasia, hypomineralization/maturation defects, and the abnormal shapes of permanent teeth.[21] When present, developmental enamel defects are also frequently associated with dental caries in preschool children,[22] and clinically occur with discoloration and esthetics problems, tooth sensitivity, wear, and erosion.[23] The main goals of monitoring tooth developmental abnormalities are an early diagnosis, the improvement of appearance and function, the preservation of dentition, the prevention of complications, and the improvement of quality of life.[24] The least invasive treatment possible contributes to pulp protection without a further loss of hard tissues, delaying more invasive treatment options as long as possible. Remineralization products alone or combined with CO_2 laser irradiation,[25] or CO_2 laser irradiation in different protocols, and resin composites or modified glass ionomer restorations have been suggested to treat the dentinal hypersensitivity associated with dental structure abnormalities.[26,27]

Mandibular premolar agenesis has been reported as the most common agenesis just after third molars, ranging from 2.4% to 4.3%,[28,29] with ethnic[3,30] and gender[31] variations, revealing its genetic origin,[4,6] as reported worldwide.[3,6,30–32] Mandibular second premolar (M2P) agenesis occurs mainly with the retention and infraocclusion of the second primary molar (2pm),[33] the loss of alveolar height and width, antagonist supraeruption, and the movement of the adjacent teeth, with a possible negative influence on the sagittal and vertical dentofacial development, and increased overbites.[34–36] The loss of space and the retention of the first premolars can also occur.[28]

The 2pm has been described as having one of the longest lifespans.[37] Its infraocclusion and root resorption, or the mesial movement of the adjacent teeth seem to slightly increase after 20.[38] When present, infraocclusion worsens the prognosis more than root resorption.[39] If the 2pm is retained for a long time, its occlusal relationships must be considered, since adequate and well-distributed occlusal forces are crucial for extended survival.[40] The correlation of longevity with the presence or absence of the second permanent molar may also be pertinent.

M2P agenesis should alert to clinically important tooth anomalies, such as an increased risk of agenesis of other permanent teeth, the transposition of incisors, impaction, delayed tooth development, ectopic eruption, retained primary teeth, and different tooth size or shape abnormalities.[33,41–43]

When treating a skeletal malocclusion, it is difficult to predict the final facial growth, and the challenge becomes even greater in the presence of dental anomalies, which compromise normal function and esthetics.[44] Articles specifically relating M2P agenesis to skeletal malocclusions are extremely rare and performed in the populations seeking orthodontic treatment. Data reveals inconsistency and dependency on ethnicity. That said, there seems to be some tendency to associate M2P agenesis with Class III[44,45] or Class II/div 2[1,46] skeletal malocclusions, and with a hypodivergent growth pattern.

The diagnosis of tooth agenesis and treatment planning involve clinical evaluation and radiographic confirmation.[47] Radiographic parameters are usually obtained from orthopantomography,[42,43,48] lateral cephalograms,[49] bitewing or periapical radiographs,[50] and cone-beam computed tomography (CBCT) if the conventional

radiography fails to provide a correct diagnosis, but not as a standard method of diagnosis,[51] considering a more significant radiation risk[52] and a higher economic cost relative to the conventional radiography.[53] In cases with palatal clefts involving complex decisions, like osseous grafts or the need to preserve crucial anatomic structures, CBCT may be required. Combining low mAs (16) and kVp (70) with a small voxel size (180 μm) enables the association of a low effective dose with high image quality.[54] More recently, the possibility of using magnetic resonance imaging (MRI) as a feasible tool for orthodontic treatment planning without radiation exposure has been described, through transforming the acquired data into lateral cephalograms, allowing reliable measurements, similar to those applied in orthodontics routine or related disciplines, such as orthognathic surgery, despite the need for specific post-processing software and an experienced user.[55] Magnetic resonance imaging may also be an alternative diagnostic tool for three-dimensional (3D) cephalometric analysis, with an excellent agreement with the reference measurements of CBCT, the accepted gold standard for 3D cephalometric analysis.[56]

The careful examination of orthopantomograms identifies abnormalities in number (hypodontia, oligodontia and hyperdontia), size (microdontia and macrodontia), structure (amelogenesis imperfecta, dentinogenesis imperfecta and dentin dysplasia), position (transposition, ectopia, displacement, impaction, and inversion), and shape (fusion/germination, dilaceration and taurodontism), most of them asymptomatic.[57] Such data is precious in syndromic patients,[10,58] as these patients need periodical dental and orthodontic supervision to prevent or control the subsequent oral problems.

The early detection of agenesis is crucial for an appropriate and reasonable interceptive treatment plan for a missing M2P.[49] Mandibular post-rotation and the increased total gonial angle associated with infraocclusion have been described, reinforcing the need for an early diagnosis[59] and the intervention of a multidisciplinary team.[60] The 2pm retention, with or without infraocclusion, with the absence of M2P agenesis must be wisely identified, as a treatment plan in the presence of ankylosis is more or less ascertained.[61] Meanwhile, the extraction of the 2pm with a missing M2P may offer benefits, such as avoiding prosthetic replacement, and reducing or eliminating the need for orthodontic appliances once spontaneous space closure occurs, especially if the second permanent molar has not yet erupted.[62]

In cases with dental crowding, autotransplantation must be considered, as it may have a good prognosis, provided it is carefully planned and timed. In growing individuals, the transplanted tooth enables the growth and development of the alveolar ridge, and may offer a permanent solution to agenesis,[63] mainly because the implant survival in children under the age of 13 is low, with most losses occurring early during the healing phase.[64] Moreover, espite decreased passive eruption in patients over 15,[65] replacement with an implant must be well-weighed, as using implants in growing children is controversial,[66] and to overcome in the future the infraocclusion of the implant-supported crown, a new restoration, orthodontic treatment, distraction osteogenesis, or coronal implant placement is often recommended.[67] Furthermore, patients with M2P agenesis have narrower and shorter mandibular cross-sections than a control group, with pronounced lingual alveolar plate and submandibular fossa, enhancing the risk of bone perforation during endosseous replacement (tooth autotransplantation or implant installation).[68] However, this constraint can be minimized with a well-established osseous diagnosis and a 3D additive manufacturing technology.[69]

A fixed prosthesis, either as a permanent partial bridge or a semi-permanent resin-bonded bridge, like an implant, restrains the growth of the alveolar process, not being a perfect solution. Despite not being focused on M2P agenesis, a study by Cahuana-Bartra et al. revealed that patients with hypodontia showed satisfaction with resin-bonded bridges over a 7-year observation period, with an 88% success.[70]

Regarding treatment options, data from 42 studies published in the years 1980–2015 presented a mean survival of 95.3%, 94.4%, 89.6%, and 60.2% for implants, autotransplants, retained primary teeth, and the conventional prostheses, respectively.[64] Meanwhile, the mean satisfaction rates for the type of treatment, i.e., for implants, the conventional prostheses, autotransplants, and orthodontic space closure, were 93.4%, 76.6%, 72.0%, and 65.5%, respectively.[64] Yet, in the last two decades, there seems to be a shift in therapeutic decision-making, with a tendency to prefer orthodontic space closure to space opening and prosthetic replacement, perhaps reflecting a greater optimism with biomechanical strategies since the implementation of temporary anchorage devices (TADs) to assist in space closure, especially if the agenesis is asymmetrical,[71] as TAD-assisted space closure can be considered a safe treatment option for young patients with M2P agenesis.[72] Autotransplants and deciduous teeth were reported to have low annual failure rates,[64] and seem appropriate for children and adolescents at a low cost.The review found a mean observation time of 4.1 years for children, 4.9 years for adolescents (<18 years) and 6.4 years for adults in the included studies.[64] In cases with the agenesis of multiple teeth, the attachment of an overdenture on the remaining teeth can be considered,[73] provided the daily oral hygiene and routine maintenance are feasible.

Concerning M2P agenesis, despite the agenesis being located posteriorly, the patient's self-image can play an essential role in making clinical treatment decisions and the dentist's esthetic judgment.[74] Patients and their families would probably benefit from an oral health-related quality of life (OHRQoL) questionnaire to accelerate the implementation of treatment. Despite this kind of agenesis

being presumably less esthetically compromising, children with oligodontia were described as having poorer scores as compared even to their parents, with no direct relationship with the number of missing teeth, exhibiting significantly worse social well-being scores for anterior agenesis and better ones whenever there was a retained primary tooth, probably masking the effect of the permanent tooth agenesis, especially in younger children.[75] One of the optimum treatment standards in pediatric dentistry is the esthetic demand, which impacts on the child's OHRQoL, and subsequently the child's general health-related quality of life. Thus, it is beneficial to the dentist to identify the influence of esthetic restorations on the OHRQoL of preschool children.[76] The OHRQoL of preschool children treated with zirconia crowns was described as significantly better as compared to those who received resin-bonded composite strip crowns.[77] An adapted and validated Early Childhood Oral Health Impact Scale (ECOHIS) questionnaire could be an excellent tool to distinguish children without agenesis from those with a moderate to high percentage of missing teeth, like it was made for caries experience,[77] or to determine the impact of agenesis treatment on OHRQoL in situations of a low percentage of missing teeth.[78] There is still no evidence of a long-term survival of the mandibular 2pm, and to accurately answer the typical questions from the patient: "For how long can my primary tooth survive if we decide to leave it in situ?" or "Will it be healthy and functional?", is yet tricky.[38] Well-designed longitudinal, prospective controlled studies comparing the advantages and disadvantages of the interceptive extraction of the primary molar or preserving the primary molar as a substitute for the absent permanent tooth in children in the early mixed dentition are an emergent need.[79]

Using video-sharing platforms and virtual social networks can be helpful to spread information among patients. Nevertheless, the information disseminated should be scrutinized and weighed with well-defined criteria,[80,81] and healthcare professionals, academic institutions and professional organizations should direct patients to reliable and more authoritative information sources, allowing consumers to critically assimilate the information posted in order to make effective healthcare decisions.[82,83]

Teledentistry for oral screening, especially in school-based programs, rural areas, and areas with limited access to care, could also be used to identify tooth agenesis. Teleconsultations are possible and valid,[84] if the business model and the cost-effectiveness concerns related to the time spent, particularly in the context of developing countries, are taken into account, as the preferred way seems to be a video-conference, followed by a phone call.[85]

Some of the cases of missing teeth are complex clinical situations that require treatment involving not only the dentist, but also other medical specialists, such as the internist, the neurologist, the psychiatrist, the endocrinologist, the cardiologist, and the dermatologist.[64]

Considering all these concepts, with this study, we aimed to contribute to the understanding of the natural evolution of the second primary molar (2pm) in a population not selected by orthodontic issues, and to estimate the longevity of 2pm, given its root resorption, occlusal positioning and the behavior of the adjacent teeth, with the prospect of finding scientific evidence to encourage its preservation in the oral cavity as a lasting therapeutic option, but also bearing in mind that low-income countries have financial constrains regarding complex treatment, such as orthodontics or implant-supported crowns.

To frame our study theoretically, a mini-narrative review was done.

Material and methods

An observational, cross-sectional and retrospective study was developed by analyzing digital orthopantomograms from the clinical records of outpatients at the Dental Clinic of the University Institute of Health Sciences (IUCS)/CESPU, Gandra, Portugal, from 4 consecutive years (January 2014–December 2017).

The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines for reporting observational studies were followed. The ethical approval was provided by the Ethics Committee at IUCS/CESPU.

The hypotheses formulated were: H_1 – the second primary molar (2pm) has the root and occlusal conditions to preserve the space corresponding to the absent permanent tooth for at least 15 years; and H_0 – the second primary molar (2pm) does not have the root or occlusal conditions to preserve the space corresponding to the missing permanent tooth.

Study population and data collection

Based on a preliminary sample of 12,949 orthopantomograms, 6,001 (46.34%) from males and 6,948 (53.66%) from females, 61 patients – 25 (40.98%) males and 36 (59.02%) females, aged 7–36 years, with a mean age of 16.38 ±7.96 years – were diagnosed simultaneously with M2P agenesis and the 2pm retention. The 3rd quadrant and the 4th quadrant (tooth 3.5 or 4.5) were registered separately.

Oligodontia, cleft palate, syndromic cases, bone defects, the evidence of surgery or extraction, trauma, fractures, or previous orthodontic treatment were excluded.

Error of the method

The orthopantomograms were acquired with a digital device (PaX-400; Vatech, Hwaseong, South Korea) and after standardized photographic printing, analyzed to determine which teeth were present, absent or extracted. The subsequent measurements were done with

an orthodontic ruler (Dentaurum, Ispringen, Germany), following the method of Odeh et al.[86] One investigator systematically observed all orthopantomograms, and a second one blindly and randomly followed half of the sample for calibration and to discuss possible doubts. An administrative employee blindly coded the orthopantomograms to avoid the examination bias. Afterward, the results of the examinations were sorted by groups for statistical comparisons.

Evaluation of the measurement error

In evaluating the intra-observer and inter-observer variability corresponding to the observations of the variables involved in this investigation, 13 randomly selected patients from the initial sample were considered. In the inter-observer variability study, the 13 individuals were evaluated by 2 independent observers. For assessing the intra-observer variability, the investigator performed measurements on the 13 patients on 2 occasions, with a 2-month interval. The variability was evaluated through the intraclass correlation coefficient (ICC) with the determination of the confidence interval (*CI*). Table 1 shows the mean (*M*) and standard deviation (*SD*) values with regard to the examined variables of a quantitative nature, and the respective ICCs assessed by the same investigator (Observer 1).

Similar mean values were observed at both time points. The ICC values were considered high (1 corresponds to a perfect agreement) and very close to each other, revealing a good agreement between the 2 observations for all quantitative variables.

The statistical values (*M* ±*SD*) to assess the inter-observer variability were calculated based on measurements from 2 different investigators (Observer 1 and Observer 2). They are shown in Table 2, together with the ICC values.

Similar mean values were observed for the 2 observers. The ICC values were high and very close to each other, verifying a good agreement for all quantitative variables and suggesting the reliability of the analyzed data.

Table 1. Intra-observer agreement of the variables under study

Variable	Observation 1 *M* ±*SD*	Observation 2 *M* ±*SD*	ICC (95% *CI*)
RR	0.36 ±0.26	0.38 ±0.30	0.950 (0.835–0.985)
Width X [mm]	13.31 ±1.70	13.54 ±1.20	0.935 (0.788–0.980)
Width Y [mm]	10.77 ±2.17	10.84 ±2.30	0.926 (0.759–0.978)
Infraocclusion [mm]	2.46 ±1.07	2.67 ±1.16	0.977 (0.924–0.993)

M – mean; *SD* – standard deviation; ICC – intraclass correlation coefficient; *CI* – confidence interval; RR – root resorption; width X – mesiodistal width of the second primary molar (2pm); width Y – distance between the mesial face of the first permanent molar and the distal face of the first primary molar or the first permanent premolar.

Table 2. Inter-observer agreement of the variables under study

Variable	Observer 1 *M* ±*SD*	Observer 2 *M* ±*SD*	ICC (95% *CI*)
RR	0.37 ±0.26	0.38 ±0.24	0.835 (0.460–0.950)
Width X [mm]	13.31 ±1.70	13.63 ±1.45	0.759 (0.345–0.920)
Width Y [mm]	10.77 ±2.17	10.38 ±1.81	0.926 (0.759–0.978)
Infraocclusion [mm]	2.46 ±1.07	2.46 ±1.05	0.978 (0.925–0.993)

Sample grouping

The groups were as follows: group 1 – the first permanent molar in occlusion (n = 23); and group 2 – the second permanent molar also in occlusion (n = 38). A subdivision was made to correlate root resorption (RR), width X, width Y, infraocclusion, and age.

Orthopantomography analysis

Methods and tools were defined as follows:

- the degree of RR, evaluated according to a 6-point scale (the Bjerklin and Bennett method[38]) (Fig. 1A), assessing the distal and mesial roots. The highest RR value was scored for the tooth; scores 4, 5 or 6 (i.e., 3/4 of the root or more resorbed) were considered as a poor root condition;
- infraocclusion (the distance from the occlusal plane to the occlusal surface of the 2pm in millimeters) (Kurol's method[87]) (Fig. 1B);
- width Y (the distance between the mesial face of the first permanent molar and the distal face of the first primary molar or the first permanent premolar in millimeters) (Fig. 1C); and
- width X (the mesiodistal width of the 2pm in millimeters) (Fig. 1D).

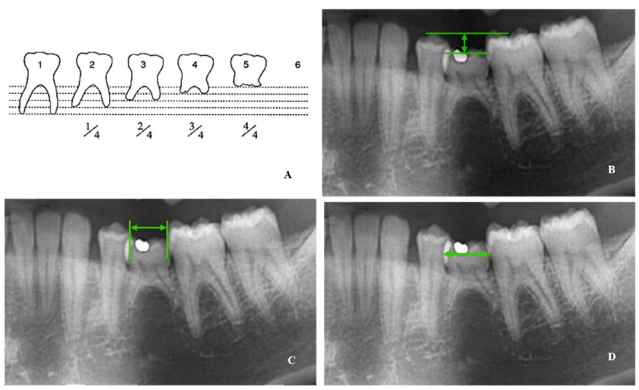

Fig. 1. A – different root resorption (RR) stages, measuring the quarters of each root (adapted from Bjerklin and Bennett (2000)[38]); B – measurement of the primary tooth infraocclusion; C – measurement of width Y; D – measurement of width X

Statistical analysis

The descriptive data was presented as mean and standard deviation (*M* ±*SD*), or as frequency and percentage (*n* (%)). The χ^2 test was used to assess the existence of dependence between 2 qualitative variables. The Monte Carlo simulation techniques were used whenever the applicability conditions of the χ^2 test were not met. Spearman's and/or Pearson's correlation coefficients were used to assess the degree of association between 2 variables (ordinal or continuous). Comparisons between groups, based on quantitative variables, were performed with the use of parametric tests whenever their applicability assumptions were satisfactory; otherwise, nonparametric alternatives were used. The Shapiro–Wilk test assessed the assumption of normality and Levene's test – the homogeneity of variance. A *p*-value ≤0.05 was considered statistically significant. Descriptive, graphical and inferential statistical analyses were performed using the IBM SPSS Statistics for Windows software, v. 20.0 (IBM Corp., Armonk, USA).

Results

Group 1 presented a mean age significantly lower than group 2 (9.39 vs. 20.61 years) ($p < 0.001$).

The prevalence of M2P agenesis associated with the 2pm retention was 0.47% in the total sample, affecting tooth 4.5 in 50.8% ($n = 31$) and tooth 3.5 in 49.2% ($n = 30$) of the cases. The inferential statistical analysis indicated that the percentage of patients affected by tooth 3.5 or 4.5 agenesis was not significantly different from 50.0%, so prevalence was similar in both quadrants.

The RR values were significantly different between the groups ($p = 0.001$). Group 1 had a higher frequency of low values, while group 2 had a higher frequency of values 0.50 (2/4 of RR) and 0.75 (3/4 of RR). The root resorption of the 2pm increased when the second permanent molar was also in occlusion, but it was impossible to detect its ending (Fig. 2A).

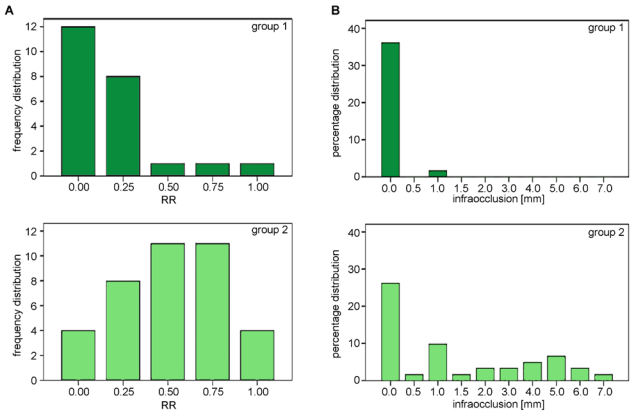

Fig. 2. A – distribution of root resorption (RR) according to group; B – distribution of infraocclusion according to group

Infraocclusion differed significantly between the groups ($p = 0.036$). The most frequent value was 0 mm (in occlusion) for both groups. In group 1, the values ranged from 0 mm to 1 mm, while in group 2 they ranged from 0 mm to 7 mm, being more often 0 mm or 1 mm, but increasing with age (Fig. 2B).

With the fundamental hypothesis being a zero correlation coefficient, the relationship between width X and width Y was compared among the groups. The correlation coefficients and *p*-values associated with the statistical test were calculated (Table 3). The dispersion diagram between width X and width Y according to group is displayed in Fig. 3.

The mean width X was significantly higher than the mean width Y in both groups, so the influence of the group on that difference was analyzed. We found a mean difference between width X and width Y of 2.09 mm in group 1 and of 2.77 mm in group 2. However, the equality between these 2 averages was not rejected ($p = 0.269$) (Table 4).

The correlation coefficients for the variables RR, width X, width Y, and infraocclusion with regard to age were calculated separately in the total sample, group 1 and group 2. Low correlation coefficients were found, significantly different from zero only for the whole sample. The strongest correlation with age was found for RR and infraocclusion. There was also a weak correlation between age and width Y, but still significantly different from zero (Table 5).

Table 3. Relationship between width X and width Y according to group

Statistics	Group 1	Group 2
r	0.408	–0.079
p-value	0.048*	0.639

* statistically significant.

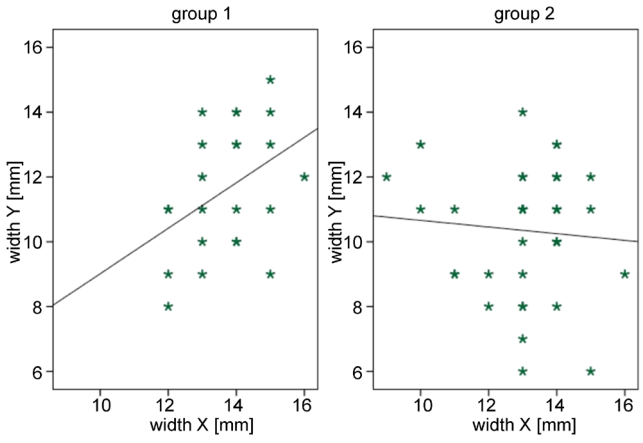

Fig. 3. Dispersion diagram between width X and width Y according to group

Table 4. Comparison between width X and width Y

Group	Width X [mm]	Width Y [mm]	*p*-value
Group 1	13.70 ±1.15	11.61 ±1.97	<0.001*
Group 2	13.11 ±1.97	10.34 ±1.94	<0.001*

Data presented as *M* ±*SD*. * statistically significant.

Table 5. Correlation between the variables root resorption (RR), width X, width Y, and infraocclusion and age

Variable	Total sample		Group 1		Group 2	
	r	*p*-value	r	*p*-value	r	*p*-value
RR	0.408	0.001*	0.066	0.763	–0.112	0.504
Width X	–0.129	0.324	–0.087	0.694	–0.032	0.849
Width Y	–0.261	0.042*	–0.167	0.445	–0.045	0.790
Infraocclusion	0.483	<0.001*	–0.248	0.255	0.142	0.394

* statistically significant.

To confirm those results, age categorization for each group was done to determine how the mean values of RR, width X, width Y, and infraocclusion varied according to age subgroups.

The results are displayed in Tables 6,7 and Fig. 4. In group 1, the mean RR values were similar in both age subgroups, slightly reducing with age. In group 2, the lowest mean RR value was observed for patients over 30, followed by those aged 21–25 years; for subgroup 26–30 years, the mean RR value was similar to those observed in the first 3 age subgroups. Comparing the groups, group 1 presented lower RR values.

In group 2, the mean infraocclusion was approx. 0 mm for patients under 11 years of age, with a progressive increase up to 21–25 years, followed by a decrease with age. In group 1, the average infraocclusion was approx. 0 mm in both age subgroups.

Regarding width X, in group 2, the subgroups up to 20 years and that of 26–30 years showed similar mean values.

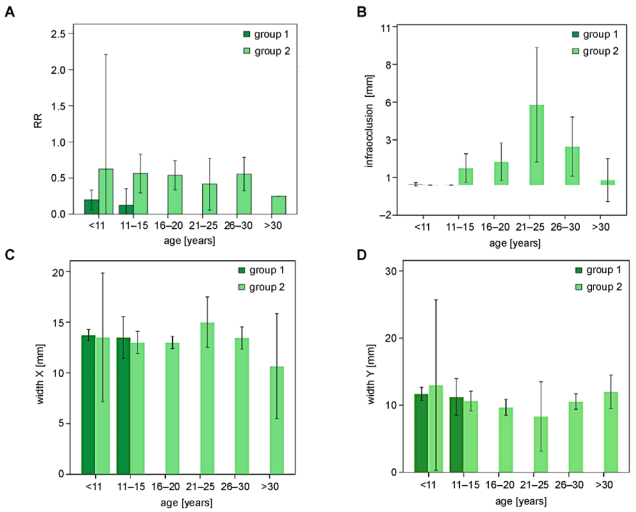

Fig. 4. A – root resorption (RR) according to group and age subgroups; B – infraocclusion according to group and age subgroups; C – width X according to group and age subgroups; D – width Y according to group and age subgroups

Table 6. Root resorption (RR), width X, width Y, and infraocclusion according to age subgroups in group 1 ($n = 23$)

Variable	Age [years]	
	<11 $n = 19$	11–15 $n = 4$
RR	0.20 ±0.23	0.13 ±0.14
Width X [mm]	13.74 ±1.15	13.50 ±1.29
Width Y [mm]	11.68 ±2.06	11.25 ±1.72
Infraocclusion [mm]	0.05 ±0.23	0.00

Data presented as *M* ±*SD*.

The highest value was observed in subgroup 21–25 years and the lowest in patients over 30. In group 1, no differences were found. Globally, group 1 and group 2 did not differ.

Regarding width Y, in group 2, patients under 11 or over 30 showed the highest values, and subgroup 21–25 years showed the lowest value. In group 1, the mean width Y was nearly equal in both subgroups. Globally, group 1 and group 2 did not differ.

No significant movement of the adjacent teeth was observed in any of the groups or subgroups, so the vertical position of the teeth was apparently maintained.

Table 7. Root resorption (RR), width X, width Y, and infraocclusion according to age subgroups in group 2 ($n = 38$)

Variable	Age [years]					
	<11 $n = 2$	11–15 $n = 8$	16–20 $n = 13$	21–25 $n = 3$	26–30 $n = 9$	>30 $n = 3$
RR	0.63 ±0.18	0.56 ±0.32	0.54 ±0.34	0.42 ±0.14	0.56 ±0.30	0.25 ±0.00
Width X [mm]	13.50 ±0.71	13.00 ±1.31	13.00 ±1.00	15.00 ±1.00	13.44 ±2.56	10.67 ±2.08
Width Y [mm]	13.00 ±1.41	10.63 ±1.77	9.69 ±1.93	8.33 ±2.08	10.56 ±1.42	12.00 ±1.00
Infraocclusion [mm]	0.00	1.13 ±1.12	1.54 ±2.08	5.33 ±1.53	2.56 ±2.56	0.33 ±0.58

Data presented as *M* ±*SD*.

Discussion

The clinical decision to treat M2P agenesis associated with the retained 2pm is a challenging issue,[60] and the options to extract, thus allowing space closure, to prosthetically replace the missing tooth or to maintain the primary tooth in the arch implies reflection over various parameters, such as the health of the crown, pulp and root of the primary tooth as well as of the surrounding bone,[50] the vertical position of the primary tooth relative to the occlusal plane; the presence of ankylosis of the primary tooth,[60] the patient's sagittal and vertical skeletal individual characteristics,[62,88] the occlusal relationships and dental crowding, the patient's dental and chronological age,[62] the presence of third molars, and the patient's preference for specific treatment or the expenditure of money.[29,34,35]

Whenever the delayed exfoliation of the 2pm is detected, the diagnosis must necessarily be completed by the radiographic observation and verification of M2P agenesis,[47] as if it occurs, the therapeutic option is an urgent need, and in the majority of the cases, it is a complex therapy.

Based on the literature, globally, we can say that a healthy 2pm with no signs of ankylosis, no carious lesions or extensive restorations could be maintained with the expectation of extended survival. Nevertheless, the anteroposterior arch length discrepancy must be controlled, sometimes by carrying out mesial and distal stripping, with a 2–3-millimeter reduction of the coronal length of the 2pm. One must be careful not to produce pulp lesions and be aware that such treatment is advisable mainly if later replacement with an implant is feasible. We must also be mindful that preserving the 2pm in function can have occlusal repercussions.

Also, in general, patients with minimal crowding, deep overbites, retrusive incisors, decreased lower facial heights, or flat mandibular planes may be candidates for no extraction, maintaining the 2pm for as long as possible. In the case of significant crowding, dental protrusion, minimal overbites or open bites, incisal inclination within a normal range, and increased lower facial heights, patients often benefit from extraction and space closure, but also with the extraction of the remaining 3 second premolars.[89] Meanwhile, based on clinical experience, we are confident that the premolar space closure with the use of an orthodontic device is more cost-effective, mainly if TADs are used to assist in space closure,[71] often without the need for bone grafting, manual bone spreading[90] or osseodensification to increase ridge dimensions in a narrow alveolar ridge[91] before implant placement, or using a prosthetic restoration with inherent costly maintenance as compared to that of a natural tooth.

Bearing in mind those concepts, we chose patients from our University's Dental Clinic as the target population. The only initial requirement was having the digital orthopantomography taken before the first consultation, available in the clinical records. In terms of selection criteria, the population differed from most of the populations from previous studies, as it was a raw population, i.e., it was not related to the orthodontics or various pediatric dentistry departments, so the patients had no prior diagnosis of an orthodontic issue or agenesis. This fact that could contribute to a certain bias.

Another peculiarity is that the average monthly income per capita of that population is less than half the country's mean reference value, which restricts onerous treatment, making the possibility of keeping the 2pm in function for a long time a socially fundamental therapeutic option.

Furthermore, since the clinical decision should be made as early as possible, ideally still in the early pediatric age (<9 years), we did not impose the age restriction as an exclusion criterion and, by doing that, we expected to have a more realistic view of natural evolution in cases not intervened.

In our selected sample, the mean age for group 1 was below that of group 2, as the established criterion for the eruption of molars was immediately an age constraint. Splitting the sample by the age of 11, i.e., by the expected usual age of the exfoliation of the 2pm, had a purpose to possibly identify differences in the biological behavior of a not yet exfoliated tooth and of a retained one. Nevertheless, we must emphasize that our population comprised younger patients than the majority of previous studies, which is a pertinent issue if we assume that the infraocclusion of the mandibular 2pm can be diagnosed since the age of 5 with a peak at 8–9 years,[92] a statement that is inconsistent with our findings, as we found a close to 0 incidence below the age of 11 and a peak in the subgroup of 21–25 years.

A 1.44 times higher frequency of M2P agenesis was found in females, in accordance with another retrospective study,[93] but in conflict with one conducted on an Asian population,[2] possibly reflecting different selection criteria and the different genetic origin of the population.[30] In a Portuguese population of a similar origin, a study on the prevalence of the dental agenesis excluding third molars, conducted in 2005–2009, found a 1.30 times greater prevalence in females.[32] In that study, the total prevalence of M2P agenesis was higher (6.0%) than ours, certainly due to the fact that we also required the presence of the retained 2pm. As back in 2005–2009, digital orthopantomography was not yet at our disposal, despite the temptation to enlarge our sample, that previous sample was not included in this study to avoid bias.

Although this is a cross-sectional study, RR, infraocclusion, width Y, and width X were correlated with age. The occasional high RR values correlated with M2P agenesis are not a surprise and were related to older patients, as resorption is expected to increase with age.[39] As group 2 had the second permanent molar in occlusion, we can extrapolate that only this group was older than 12 years. Consequently, we could compare our results with those

of Bjerklin and Bennett, who revealed a 60% mesial root resorption and a 46% distal root resorption at the age of 11–20 years for the 2pm, with a very slow great inter-individual variation process.[38]

The prevalence of M2P agenesis with the retained 2pm was similar in both quadrants. Arai found the same in the Japanese population,[2] but De Stefani et al. found a preponderance of left M2P agenesis in an Italian sample.[1] Symmetry may complicate the therapeutic decision in cases with no dental crowding (common in agenesis),[41] deep overbites or restrained lower facial development, as the normal mandibular development can be compromised bilaterally, advising the maintenance of the primary tooth.[89]

Contrariwise, if the extraction of the 2pm is recommended due to decay or root resorption, it should be done as soon as possible to allow spontaneous effective space closure,[29] preventing the abnormal movement of the adjacent teeth or steeper occlusal curves, thus avoiding the need for later orthodontic treatment.[94,95] It should be done soon after 9 years of age, but the first premolar should have at least half of the root length already developed.[89] Whenever possible, controlled mesial and distal stripping, followed by the hemi-sectioning of the 2pm before extraction should be performed, producing the controlled mesial movement of the first permanent molar.[89]

Extraction must be performed with caution to maintain the cortical walls, especially in cases of ankylosis, as the alveolar ridge progressively loses width, mainly due to the loss of the buccal side of the ridge,[67] and if extraction is performed after the eruption of the second permanent molar, space maintainers are not recommended, even if implants are planned. In such a situation, the drifting of the adjacent teeth should be allowed for some space closure, and the teeth should be posteriorly verticalized, recreating space for the implant, and thus maintaining the ridge.

A recent 3D finite element analysis found that the kind of occlusal forces influenced the pattern of root resorption.[40] Other authors showed that the 2pm could remain stable without additional root resorption after 20 or up to 15 years after the exfoliation age.[39] Another retrospective radiographic study with patients aged 21–77 years found an insignificant reduction of the root length of all primary teeth, on average by 0.16 mm over 5 years.[50] In our study, group 2 presented worse cases of root resorption, despite the most frequent values being 0.50–0.75, which is in line with Bjerklin and Bennett.[38]

The mean infraocclusion was approx. 0 mm in the 2 age subgroups considered for group 1, as in a study by Bjerklin et al.[28] For group 2, this average was also approx. 0 mm in patients aged <11 years, with an increase up to the age 21–25 years, followed by a marked decrease. However, in a previous study, Bjerklin and Bennett concluded that 55% of patients with M2P agenesis and the retained 2pm had infraocclusion of a value far exceeding ours,[38] probably due to the measurement reference points, necessarily modified with regard to the patient age, as observed in other studies.[86,87] This aspect should be further explored, as the reference points used for the determination of infraocclusion have not been standardized.[96] In 2016, objective criteria for measuring infraocclusion with a high reproducibility of the results were described,[96] but their applicability to different age groups is yet to be proven.

Our findings regarding no gender prevalence and the lack of a significant association between infraocclusion and the arch side are compatible with a previous study, which further described the 2pm as the most infraoccluded tooth.[86] Another study, not requiring the retained 2pm, found a slight preponderance of bilateral agenesis and unilateral right-sided agenesis, and a significantly higher prevalence of the microdontia of maxillary lateral incisors.[43]

Width Y remained stable throughout age periods, with no significant loss of space and no place for mesial movement. Our findings for groups 1 and 2 are compatible with data from other studies,[95] and are probably due to the close to 0 mm infraocclusion mean value. Although minimal, it must be monitored in some cases, as early infraocclusion is detrimental and leads to the tooth loss. Even so, paradoxically, teeth with short roots are more prone to be stable over time.[37]

Maintaining the 2pm as a therapeutic option may compromise occlusion due to the unavoidable Bolton discrepancy caused by a larger mesiodistal size of the 2pm relative to its permanent successor.[95] To equate occlusal interference or to reduce the occlusal surface width, it is advisable to diminish occlusal forces.[40]

Given the possibility of temporomandibular joint dysfunctions and the desired age of the agenesis diagnosis, despite MRI still being the gold standard for the identification of joint structures, the ultrasound scan should be considered, regardless of its lower diagnostic efficiency in evaluating the disk position during joint movements, due to some clinical advantages in terms of costs, accessibility and easier monitoring of young patients. Nevertheless, the obtained data must be corroborated by clinical and anamnestic data.[97,98]

M2P agenesis with the retained 2pm is a challenge,[95,99] with several issues to be considered, such as extracting or not, or re-anatomizing, restoring, or preserving the 2pm.[37,40,92,99,100] Clues are scarce, as revealed by the search in the databases, as only one systematic review with a specific survival rate for the 2pm (83–93%) was found, and it was based on the data extracted from only 4 longitudinal observational studies with follow-ups of 5–15 years.[100]

The prognostic factors are root resorption, infraocclusion, caries/restorations, and the periodontal status.[100] If ankylosis is present, a treatment plan is urgently required, and extraction/space closure, extraction/transplantation or extraction/prosthesis must be considered as the best plan,[61] provided the loss of the alveolar crest is equated since the 3rd month after the extraction of the primary tooth.[67] Another concern is that M2P agenesis is frequently associated with other tooth anomalies, even

in non-syndromic cases, especially with the agenesis of third molars from the same quadrant, which may be found in 48% of patients.[33,48] As a third molar should only be considered as missing after the age of 14, the decision to early extract the retained 2pm may be risky, since space closure can occur with the mesial movement of the posterior tooth sector before it is certain that a third molar is present, leaving open the possibility of the agenesis of third molars, with the consequent absence of a vertical stop for the maxillary second molar.

We found that the age of 10–15 years and 21–25 years were critical phases for the loss of the 2pm. Surviving those phases with favorable occlusal function boosts longevity, which could encourage research in populations far beyond the pediatric age.

Given our results, hypothesis H_1 was accepted, and H_0 was rejected, as we found that the 2pm had the root and occlusal conditions to preserve the space for the corresponding absent M2P for at least 25 years, a finding beneath the interval found by Bjerklin et al. (16–30 years).[28]

Longitudinal randomized clinical trials (RCTS) with the inter-study standardization of the evaluation criteria and well-defined clinical evaluation of the occlusion/function parameters are needed to calculate the real mean longevity of these second primary molars and to support the general dentist, especially when there are no other reasons for carrying out orthodontic treatment.

Limitations

The retrospective design is a limitation of the present study. Nevertheless, the original sample was considerable in terms of size. The population studied originated from the general population and not from orthodontic or pediatric dentistry patients. The selected sample had no age restriction. Another limitation might be that there were more clinical records from female patients than from male patients due to the unbalanced gender ratio in dental clinics. Still, even so, we found a relatively higher prevalence of M2P agenesis with the retained 2pm in females than in males. Working with the data obtained from patients within an age window of 29 years (7–36 years) and a mean age of 16.38 years allowed drifting away from the mean expected period for the exfoliation of the primary molar, which was a positive factor in terms of reducing the possibility of biased results due to individual differences in the exfoliation age.

Clinical considerations

Given the possible extended survival of the second primary molar, well-documented no-intervention treatment must be weighed, mainly in cases without orthodontic issues or with financial constraints, as the second primary molar can survive for a similar or even longer period as compared to a prosthetic option.

Conclusions

There is a good prognosis for the survival of the second primary molar when it remains beyond the average age of its exfoliation in cases of second premolar agenesis. In our study, we showed that it could replace the absent permanent premolar up to 36 years of age (the oldest patient found with both second premolar agenesis and the second primary molar retention).

Mandibular second premolar agenesis occurs with the retention of the mandibular second primary molar beyond the age of 25. If so, it might probably last for a long time, as root resorption decreases after that age.

The loss of space caused by the second primary molar infraocclusion is not a frequent problem, as infraocclusion is not significant in most cases, with higher values found in the oldest adult patients.

Ethics approval and consent to participate

The ethical approval was provided by the Ethics Committee at the University Institute of Health Sciences (IUCS)/CESPU, Gandra, Portugal.

Data availability

All data analyzed during this study is included in this published article.

Consent for publication

Not applicable.

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