First and second permanent molars with failed or delayed eruption: Clinical and statistical analyses

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Introduction: The aim of this work was to analyze data of patients with failed or delayed eruption of first and second permanent molars, to assess the effectiveness of the treatment methods used. **Methods:** Epidemiologic and clinical data of 125 patients (mean age 14.08 ± 4.04 years) with 197 affected molars (30 first and 167 second molars) were retrospectively analyzed. The treatment outcome was known in 161 molars after patient drop-out (20 patients with 36 molars). The cases were categorized into 8 groups according to the choice of treatment: orthodontic uprighting, surgical-orthodontic uprighting, surgical uprighting, surgical repositioning, surgical exposure, first or second molar extraction, third molar extraction, or removal of pathologic conditions. **Results:** The overall treatment outcome was positive in 141 molars (87.6%). It was positive in all cases treated with orthodontic uprighting (7 molars), surgical exposure (10 molars), surgical uprighting (38 molars), and surgical repositioning (8 molars), but it was significantly lower for surgical-orthodontic uprighting (34/48 molars, 70.8%). The positive outcome was significantly lower for inclusion (52/68 molars, 76.5%) than for early-diagnosed condition (11/11 molars, 100%) and retention (78/82 molars, 95.1%), and for total bone crown coverage (21/28 molars, 75.0%) than for osteomucosal or mucosal crown coverage (120/133 molars, 90.2%). **Conclusions:** This study demonstrates that an early diagnosis results in a better outcome regardless of the treatment used, with the number of cases with a positive outcome being higher in younger patients. (Am J Orthod Dentofacial Orthop 2019;156:355-64)

Failed or delayed eruption of first and second permanent molars is an infrequent occurrence, with a reported frequency from 0.1% to 4.6%.[1-8] Different treatment modalities have been suggested for this condition,[9-14] which negatively affects the harmonic morphologic and dimensional growth of the stomatognathic system.[13] In fact, the first and second permanent molars play a relevant role in completing the occlusion and in determining the correct occlusal vertical dimension and relationship between condyle and glenoid fossa.

In most of the literature, the term "impaction" defines the failure of tooth eruption due to the presence of a physical obstacle along its eruption pathway or an abnormal inclination of its axis. Primary and secondary retention correspond to the eruption stopping, respectively, before or after tooth emergence (related to ankyloses) in the oral cavity, without a physical barrier nor as a result of abnormal tooth position.[6,9,10,13,15]

In the present study, the terminology to define the eruption disturbances was referred to the root development degree, because the eruption stage primarily affects the treatment outcome. The terms "retention" and "inclusion" indicated the molar before or after, respectively, apical root closure, when it was still able to erupt or when it was not. Furthermore, an "early-diagnosed condition" indicated an anatomic, topographic, or pathologic condition that, if not treated before completion of the root development, might interfere with the physiologic eruption process of the molar.

The aims of the present retrospective cohort study were (1) to analyze clinical and epidemiologic

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characteristic of a large sample of first and second permanent molars with failed or delayed eruption, treated within a selected period of time at a single dental facility; and (2) to verify the effectiveness of the treatment performed, identifying factors associated with successful or unsuccessful outcome.

MATERIAL AND METHODS

In this retrospective study, the sample comprised all outpatients referred, from January 1993 to September 2016, by the Orthodontic Unit or by private dentists for the treatment of eruption disorders of first and second permanent molars to the Oral Surgery Unit, Department of Oral and Maxillofacial Sciences, "Sapienza" University, Rome, Italy.

To be included in the study sample, the patients were required to have clinical charts, radiographs, and photographs available from the start to the end of the therapy.

Patients were excluded in the absence of dental records and when the first or second molar extractions were not scheduled to treat eruption disorders.

The following data were recorded: age, sex, race, unerupted molars, local etiologic factors, eruption disturbance, molar crown coverage and axial inclination, local associated pathologic conditions, treatment modality, related therapies, treatment complications, and outcome (Table I).

Table I. Recorded data

Factor	*Responses*
Age	Years
Sex	Male, female
Race	Caucasian, Asian, Negroid
Unerupted molars	Maxillary first, mandibular first, maxillary second, mandibular second
Local etiologic factors	Abnormal eruption pathway, abnormal eruption mechanism, supernumerary tooth, cyst, odontogenic tumor, bone/soft tissue hypertrophy, iatrogenic cause
Eruption disturbance	Retention, inclusion, early-diagnosed condition
Molar crown coverage	Total bone, osteomucosal, mucosal
Molar axial inclination	Vertical, horizontal, mesial, distal, buccal, lingual
Local associated pathologic conditions	Affected molar: root anomalies, dental caries, pericoronitis, cyst; contiguous tooth: position, germ dislocation, inclination, root resorption; in the opposite jaw; in the occlusion
Treatment modality	Orthodontic uprighting, surgical-orthodontical uprighting, surgical uprighting, surgical repositioning, surgical exposure, first or second molars extraction, third molar extraction, removal of supernumerary tooth, cyst, odontogenic tumor, no treatment
Related therapies	Third molar extraction, orthodontic therapy, surgical-orthodontic treatment in association with removal of supernumerary tooth, cyst, odontogenic tumor, third molar bud transplantation
Treatment complications	Dental caries, pulp necrosis, postextraction bleeding, abscess, bracket detachment, root fracture
Outcome	Positive, negative

The cases were categorized into 8 groups according to choice of treatment: orthodontic uprighting, surgical-orthodontic uprighting, surgical uprighting, surgical repositioning, surgical exposure, first or second molar extraction, third molar extraction, or removal of pathologic conditions. For each type of treatment, the indications are described below.

Orthodontic uprighting was applied to partially erupted molars impacted against the distal surface of the adjacent tooth, given the presence of sufficient space for the anchor device placement and dental distal movement to reposition the molar in the dental arch.

Surgical-orthodontic uprighting was used in molars with total crown coverage to correct the inclination and position anomalies and consisted of crown exposure, orthodontic device positioning, and orthodontic traction to obtain molar egression at the correct place in the dental arch.

Surgical uprighting, consisting of molar tipping by the fulcrum on its root apex through gentle luxation movement, was reserved for cases in which only a minor unfavorable axial inclination prevented the normal eruption of the molar, Surgical repositioning, allowing the bodily movement of the second molar at a new position, was adopted in the presence of a major unfavorable axial inclination in patients which refused the orthodontic treatment.

To perform surgical uprighting and surgical repositioning, the space in the dental arch must be adequate to seat the molar crown.

Surgical exposure, involving the removal of bone and soft tissues above the molar crown, was chosen in the cases where these tissues hindered the eruption mechanism of the retained molars, to speed up molar egression.

First or second molar extraction was carried out when the tooth was not retrievable owing to severe abnormalities of their location and/or inclination.

Extraction of the third molar was the treatment only when it was interposed along the eruption pathway of a second molar that was still able to erupt.

The removal of supernumerary teeth or odontomas and the marsupialization of cysts were performed when these pathologic conditions prevented molar eruption.

The treatment outcome was positive when a molar with failed or delayed eruption was retrieved and correctly aligned in the dental arch. In cases where the affected molar was initially planned to be extracted because irretrievable, the outcome was considered to be positive if the other molars on the involved side were erupted and correctly aligned at the end of treatment.

After detailed descriptions of the treatment, written informed consent was obtained from each patient. The protocol was in accordance with the 1975 Declaration of Helsinki on medical protocols and ethics and its later amendments. The study was accepted by the local Ethical Committee (protocol number 3731).

Statistical analysis

A database was created with the use of Excel (Microsoft, Redmond, Wash). Descriptive statistics including mean and SD values were used. The chi-square test was used for testing relationships on categoric variables, with the Yates continuity correction applied in cases of an association between 2 dichotomous variables. Fisher exact test was used in cases where the theoretic frequencies were found to be excessively low. The independent-samples t test was used to statistically analyze the inference of age on treatment outcome. Binomial logistic regression was applied to ascertain effects on different treatment modalities of age, sex, type of unerupted molar, eruption disturbance, and molar crown coverage. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Data were evaluated with the use of standard statistical analysis software (Statistical Package for the Social Sciences, version 20.0; IBM Corp, Armonk, NY). In each test the cutoff for statistical significance was $P \leq 0.05$.

RESULTS

The study sample comprised 125 patients aged 14.08 ± 4.04 years (range 5-28 years), with 197 molars (30 first molars and 167 second molars) exhibiting altered eruption. The involvement of the permanent molars was more frequent in the mandible than the maxilla for both first (20 vs 10) and second (120 vs 47) molars. More than 1 unerupted molar was present in 47.5% of the 59 examined patients. The age differed only slightly between disturbed eruption of first (13.0 ± 6.7 years) and second (14.6 ± 2.9 years) molars. Sixty-seven patients were male (54%), with the sex ratio differing for first molars (female/male = 3/2) but not for second molars. The predominant race was white (120 patients, 96.8%). Of the 197 statistical units, inclusion and retention were diagnosed in about the same number of molars: 94 (47.7%) and 92 (46.7%), respectively. The inclusion and retention distributions were also similar when considering first and second molars independently. An early diagnosed condition was found in the remaining 11 molars (5.6%).

The treatment outcome was known in 161 molars, because 20 (36 molars) out of 125 patients were lost to follow-up. The outcome was evaluated as positive in 141 molars (87.6%): 19 out of 29 first molars (65.5%) and 122 out of 132 second molars (92.4%). To verify the effectiveness of the treatment performed, the outcome (positive/negative) was correlated with the clinical variables. The age of the patient affected the treatment outcome (Fig 1): Mean age of patients with a positive outcome was 13.68 ± 3.73 whereas that of patients with a negative outcome was 16.00 ± 6.22, but this was significant only for first molars ($P = 0.048$). Sex, race, jaw side (left or right), and etiologic factors did not affect the outcome.

Retention (78/82 molars, 95.1%) and early-diagnosed condition (11/11 molars, 100%) showed positive outcome significantly higher than inclusion (52/68 molars, 76.5%; $\chi^2_{(1)} = 13.6$; $P = 0.001$).

Regarding molars, positive outcome was more common in the mandible (108/117 molars, 92.3%) than the maxilla (33/44 molars, 75%) and was significant for first molars (16/20 mandibular, 80%; 3/9 maxillary, 33.3%; $\chi^2_{(1)} = 5.98$; $P = 0.032$) but not for second molars (92/97 mandibular, 94.8%, 30/35 maxillary, 85.7%; $\chi^2_{(1)} = 3.06$; $P = 0.129$).

Furthermore the prevalence of a positive outcome was significantly lower for total bone crown coverage (21/28 molar, 75.0%) than for osteomucosal or mucosal crown coverage (120/133 molars, 90.2%; $\chi^2_{(1)} = 12.2$; $P = 0.016$; Figure 2), whereas axial inclination of the affected molars did not affect the outcome (Fig 3).

Pathologic associated conditions, diagnosed in 33 out of 197 molars (16.8%), were found in 30 out of 161 molars in which the treatment outcome was known (18.6%).

Considering treatment modalities (Fig 4), compared with the overall prevalence of 87.6%, surgical uprighting reached positive outcome in all 38 treated molars, with a statistically significant difference ($\chi^2_{(1)} = 5.87$; $P = 0.015$). The positive outcome of this group can be related to the preexisting positive conditions requested for this approach: adequate space for molar positioning and minor alteration of molar inclination in patients with no other orthodontic treatment need. The outcome was also positive in all cases with surgical exposure

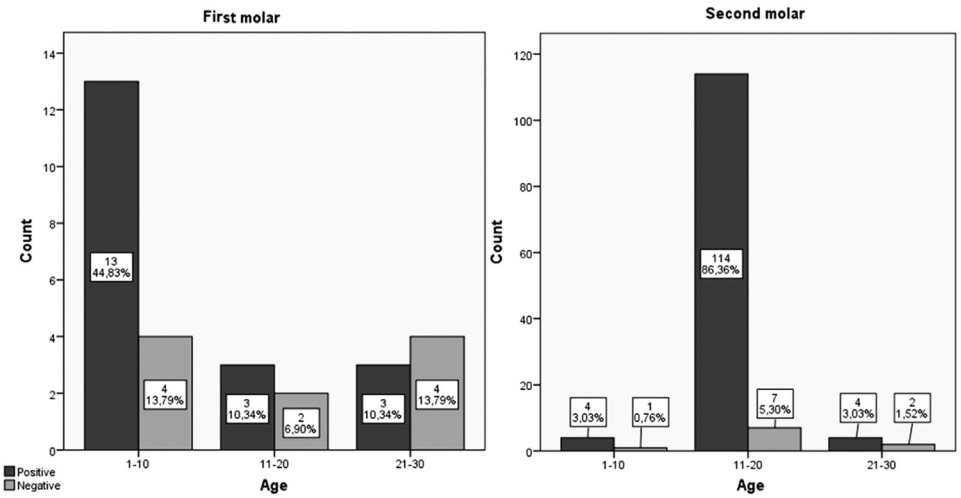

Fig 1. Treatment outcome of the 161 unerupted first and second molars according to age.

(10 molars), orthodontic uprighting (7 molars), and surgical repositioning (8 molars), but these did not reach significance owing to the small number of molars. The positive outcome for surgical repositioning was considered only for the alignment goal and did not consider possible risk such as pulp necrosis and subsequent endodontic need. The removal of pathologic conditions that prevented molar eruption, such as odontomas, supernumerary teeth, and cysts, resulted in an excellent prognosis (18/18 molars). In a 13-year-old male patient with no orthodontic treatment need and agenesis of all 4 third molars, the delayed eruption of the maxillary 2 second molars in the correct eruption pathway was resolved over 3 years without therapy. The choice of the "wait and see" approach was related to the third molars' absence and the noncompleted root formation of the maxillary second molars; it should not be considered as the rule, especially for mandibular second molars impaction.

The prevalence of a positive outcome was significantly lower for surgical-orthodontic uprighting than for all other treatments (70.8% vs 94.7%; $\chi^2_{(1)} = 15.5$; $P < 0.001$), with the success rates for the second molars of 67.86% (19/28 molars) and 70% (14/20 molars) in mandible and in maxilla, respectively. When applied to first molars, surgical-orthodontic uprighting attained a positive outcome in only 1 out of 4 mandibular molars and no success among the 6 maxillary molars.

The extraction of first and second irretrievable molars, performed to enable the mesial shifting of the subsequent molar, was associated with a lower prevalence, not statistically significant, of a positive outcome (17/22 molars, 77.3%).

The extracted first molar (8 mandibular and 1 maxillary) was successfully replaced with the second molar in 2 cases by its spontaneous migration into occlusion and in 7 cases by orthodontic movement or by surgical-orthodontic uprighting (surgical exposure of the molar crown to place an anchor device for applying orthodontic forces) of the second molar, respectively erupted or not. The outcome was considered to be negative in 1 adult patient with kissing first and second molars, because after the first molar extraction only the second but not the third molar was retrieved in functional position at the occlusal plane.

To close the space of the 13 extracted second molars, both surgical-orthodontic uprighting (4/6 molars) and orthodontic movement (4/6 molars) respectively of the unerupted or erupted third molar had a good prognosis; positive outcome was also found in the only case of third molar bud transplantation in a patient who refused to receive orthodontic treatment.

Third molar extraction as the only therapy in second molar retention was used in 8 cases, with 1 failure in a 16-year-old female patient and 7 cases with a positive outcome (4 in the mandible and 3 in the maxilla) in patients aged 11-13 years.

When the logistic regression analysis was used to ascertain the effects of age, sex, unerupted molar, eruption disturbance, and molar crown coverage on the outcome of the different treatment modalities, only surgical-orthodontic uprighting was found to be statistically significant ($\chi^2_{(5)} = 24.212$; $P < 0.001$); out of 5 predictor variables, only first molar negatively affected the outcome. However, 2 variables (inclusion and total bone coverage) had higher odds of failure of the therapy (odds ratios 1.716 and 2.043, respectively; Table II).

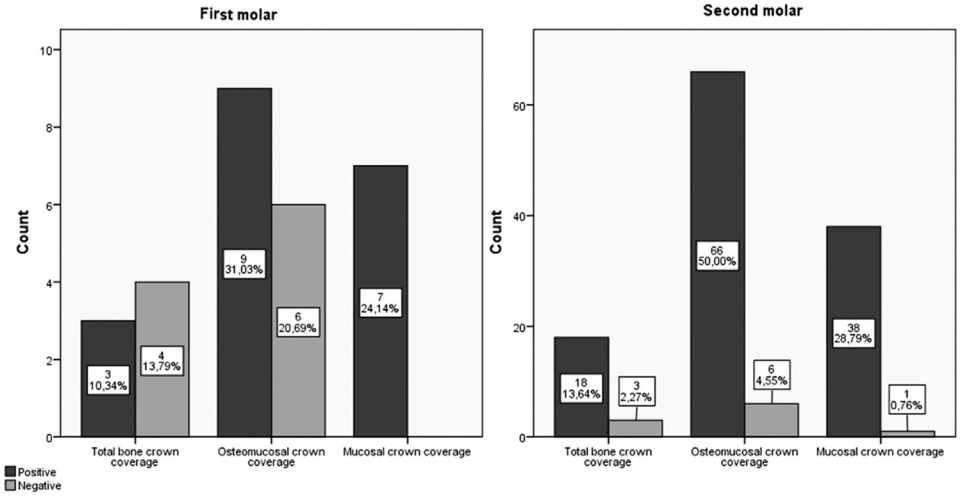

Fig 2. Treatment outcome of the 161 first and second molars according to crown coverage.

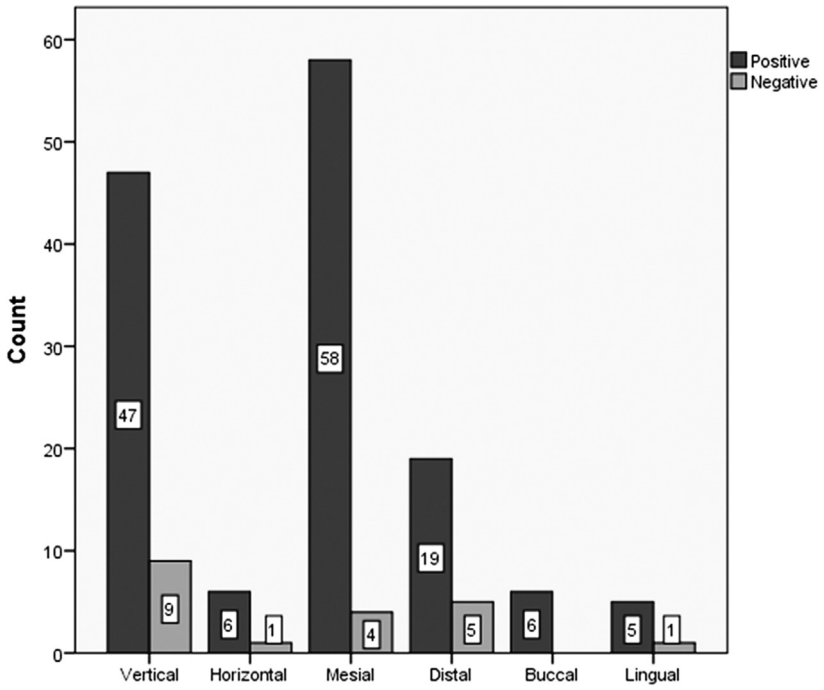

Fig 3. Treatment outcome of the 161 unerupted first and second molars according to axial inclination.

DISCUSSION

To our knowledge, apart from case reports, only 2 other studies[9,10] have analyzed treatment choice and outcome for both first and second permanent molar eruption disorders, whereas more studies on treatment modalities for second molars, especially in the mandible, are present in the literature.

The present sample (197 molars in 125 patients of mean age 14.08 ± 4.04 years) was similar in size to that reported by Bereket et al[6] (200 molars in 170 patients of mean age 22.69 ± 8.99 years) but larger than that of Valmaseda-Castellón et al[9] (43 molars in 25 patients of mean age 17.3 ± 2.2 years) and Palma et al[10] (35 molars in 26 patients of mean age 13.3 ± 2.7 years).

Considering all the 133 second molar (mean age 14.6 ± 2.9 years) of which the treatment was known, the sample was similar to that of Magnusson and

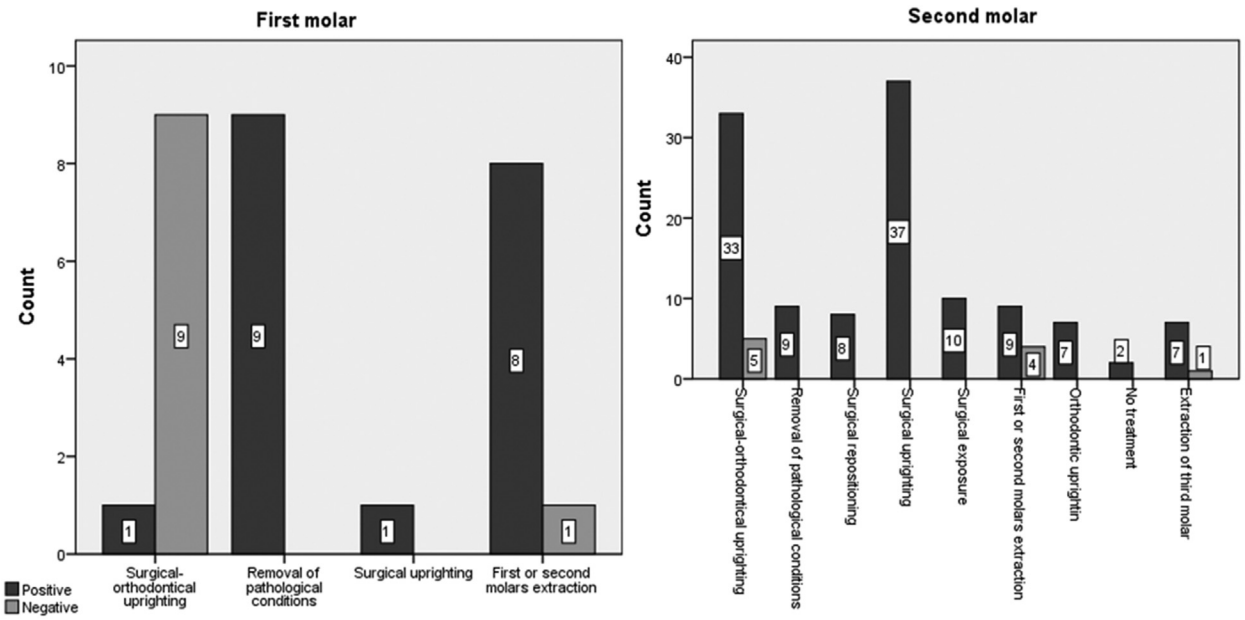

Fig 4. Treatment outcome of the 161 unerupted first and second molars according to treatment modalities.

Table II. Logistic regression predicting likelihood of surgical-orthodontic uprighting failure based on age, sex, type of unerupted molar, eruption disturbance, and molar crown coverage

							95% confidence limits for OR	
Factor	*B*	*SE*	*Wald*	*df*	*Sig*	*OR*	*Lower*	*Upper*
Age	0.008	0.115	0.005	1	0.943	1.008	0.805	1.263
Sex	−0.534	0.926	0.333	1	0.564	0.586	0.095	3.600
Unerupted first molar	3.738	1.184	9.966	1	0.002	42.026	4.126	428.046
Inclusion	0.540	1.101	0.241	1	0.624	1.716	0.198	14.848
Osteomucosal crown coverage			0.372	2	0.830			
Total bone crown coverage	0.715	1.171	0.372	1	0.542	2.043	0.206	20.283
Mucosal crown coverage	−19.367	17807.217	0.000	1	0.999	0.000	0.000	0.000
Constant	−2.039	1.877	1.179	1	0.277	0.130		

Sex is for male compared with female. Unerupted molar is for first molar compared with second molar. Eruption disturbance is for inclusion compared to retention. Molar crown coverage is for osteomucosal compared to total bone and mucosal crown coverage.

Kjellberg[15] (135 molars in 87 patients, mean age 15 years, range 11-19 years). Taking into account only the mandibular second molars, the 97 found in the present study were almost the same of the 95 reported by Wellfelt and Varpio,[11] but differed from those of Fu et al[16] (183 molars, mean age 26.5 6 ± 8.4, range 11-67 years) and Shpack et al.[17] (165 molars in 120 patients, mean age 12.8 years, range 11-15 years).

As already suggested by Johnsen,[2] the higher incidence at 12-14 years found in the present sample may be explained by the association between molar eruption disturbances and both puberty-related bone growth and hormonal changes, which are implicated in the tooth eruption process.

It is worth noting that the age at the time of diagnosis may be delayed by the frequent absence of painful symptoms and by the posterior involvement of the dental arch, which makes it more difficult to identify the absence of a molar compared with an anterior tooth, which is more easy to notice by both parents and general dentists.[9]

The male-female ratio reported in the present study was lower than those reported by Valmaseda-Castellón et al[9] and Palma et al.[10] When the mandibular

second molars are considered, the similar number of cases (85 male, 82 female) is different from the slight female predominance reported by Fu et al[16] (66 male, 74 female) and the male predominances reported by Kenrad et al[12] (60 male, 46 female) and Varpio and Wellfelt[18] (56 male, 32 female), who explained this predominance with the wider tooth diameters in male subjects combined with an inadequate skeletal size.

The lower mean age found in patients with positive outcome could be explained by the degree of root development. Several authors[9,10,19,20] considered the prognosis of different treatments for eruption disturbances of first and second molars (except surgical-orthodontic uprighting) to be more favorable when the molar roots have not yet completed their development, with the most favorable time for treating first molar eruption disturbance being before 10 years of age, and during adolescence for second molars.[9,19-21] The data reported by Valmaseda-Castellón et al[9] and Palma et al[10] support the view that the probability of successful treatment decreases dramatically in adults.

The more frequent involvement of the second molar in the present sample was in agreement with other authors[1-3,22] as was its higher percentage in the mandible than in the maxilla,[9,10] whereas the finding of prevalence of the mandibular compared with maxillary first molar differed from those of other authors.[6,9,10]

More than 1 unerupted molar was present in 47.5% of the 59 examined patients, and this percentage is higher than those of Valmaseda-Castellón et al[9] (44%) and Palma et al[10] (30%).

According to some authors,[10,14,18,22] this condition seems to suggest a genetic background. The hypothesis of genetic influence might be supported by the association between arrested eruption of mandibular second molar and the craniofacial morphology found by Vedtofte et al,[23] who identified a higher incidence of skeletal Class II, a mandibular incisal maxillary inclination, a reduced mandibular gonial angle, a greater mandibular alveolar prognathism and, a condylar growth vertical in a group of 19 patients with arrested eruption of the mandibular second molar compared with a reference group. Furthermore, Cassetta et al,[24,25] in a retrospective study on orthodontic patients, reported a positive correlation between impaction of mandibular second molar and crowding, higher angle of inclination of second molar, a smaller distance of first molar from the mandibular ramus, smaller mandibular jaw angle, and vertically directed condylar growth.

In disagreement with Palma et al,[10] who identified an abnormal eruption mechanism as the most frequent cause, in the present study abnormal eruption mechanism (slowed down or stopped progression toward the occlusal plane in the absence of mechanical obstacles) was prevalent only in first molars (14/30), whereas an abnormal eruption pathway (deviation from the physiologic tooth eruption pathway) was diagnosed in 88 out of 167 second molars.

It is worth noting that in the pathogenesis of eruption failure of the second molar, the role of an ectopic position of the third molar is still debated. According to Valmaseda-Castellón et al[9] and Palma et al,[10] third molar position should be considered as a contributory factor and not a primary cause of the second molar eruption failure.

The present data on inclusion, retention, or early-diagnosed condition, which refer to the degree of root development, are not easily comparable with those reported by other authors,[6,9,10] which used different terminology. Nevertheless, the early treatment of unerupted molars, when they have not yet completed root formation, seems to provide more predictable outcomes.[17]

The higher incidence of a positive outcome in the presence of osteomucosal or mucosal crown coverage may be probably explained because the treatment would be less complex to perform if the affected molar is very close to its normal position. Particularly, total bone coverage had higher odds of failure of surgical-orthodontic uprighting.

In the present sample, the more frequent inclinations were vertical or mesial, in contrast to Valmaseda-Castellón et al[9] reporting a clear vertical preponderance (53.5%), with no correlation with root ankylosis, whereas Wellfelt and Varpio[11] considered ankylosis to be the most likely cause of vertical inclusion. Furthermore, in agreement with Shpack et al[17] and Wellfelt and Varpio,[11] mesial inclination was the most common among mandibular second molars and was mainly attributed to an abnormal eruption pathway.

When the influence of molar inclination was correlated with the treatment outcome, the findings of the present study are consistent with Palma et al,[10] who reported no statistically significant effect, but disagree with Wellfelt and Varpio,[11] who reported the worst prognosis in the presence of distal inclination.

The presence of root anomalies, which in the present study were detected in 7 molars, should be considered an effect of local disturbances responsible for the lack of molar eruption rather than an etiologic factor.[10] An association between root anomalies and eruption disorders of second permanent molars was also reported by Vedtofte et al.[23]

Pathologic conditions affecting the adjacent teeth and the occlusion were also found by Valmaseda-Castellón et al[9] and Palma et al,[10] and they can be ascribed to 2 factors. The first factor relates to the onset of the disease when the patient is still growing and is therefore experiencing continuous dentoskeletal changes. The second factor is the frequent absence of painful or otherwise symptomatic conditions (pericoronitis, caries and periodontitis of adjacent teeth), which reduce the likelihood of both early detection and early treatment.

Regardless of treatment modalities, the overall success rate (87.6%) was significantly higher than the 50% found by Valmaseda-Castellón et al,[9] probably because of the higher age of their sample (17.3 ± 2.0 years), and the 28% reported by Palma et al,[10] who considered molar extraction to be a failure and not a treatment option. However, even if first and second molar extraction was considered as failure, the global success rate (75.5%) in the present study is still higher than those recorded by those authors.[10]

Taking into account the overall success rate only for the treatment of the mandibular second molar (92/97), the percentage of 94.8% was higher than that of 90% reported by Wellfelt and Varpio in their retrospective study on 77 patients with disturbed eruption of mandibular second molars and a mean age of 15 years.[11]

Orthodontic uprighting, applied with a positive outcome in all 7 partially erupted mandibular second molars, has been reported previously.[10-12,16] This method is considered to be more appropriate in younger patients because it is often more difficult to move teeth in adults and the latter are less tolerant of orthodontic fixed appliances. However, 2 19-year-old patients were successfully treated in the present study, so this method can be considered feasible and predictable even in young adults.[16]

The overall success rate of surgical-orthodontic uprighting (70.8%) differed from that of 100% reported by Wellfelt and Varpio,[11] but they did not account for patients lost to follow-up and those still receiving treatment.

In this modality, the only statistically significant predictor variable to affect the treatment was the first molar. The negative results reported in 9 out of 10 first molars and only 5 out of 38 second molars were related to the deep inclusion (total bone coverage) and to impaction of root apex with the mandibular canal roof or the maxillary sinus floor. The degree of root mineralization did not seem to affect the positive outcome, as evidenced by the fact that 23 out of the 33 second molars successfully treated were in inclusion and only 10 were in retention.

It is important to know that in the present retrospective study miniscrews or mini-implants were not used for orthodontic anchorage,[26,27] because all of the patients were assisted by the Italian National Health Service which does not provide these devices.

Surgical exposure, successfully performed in all 10 molars treated in the present study, may be considered a reliable technique, as already shown by Valmaseda-Castellón et al,[9] who achieved positive outcomes in 5 out of 8 molars. Nielsen et al,[28] analyzing treatment outcomes of 25 subjects with primary retention of first permanent mandibular molars, suggested that there is a high probability of eruption after surgical removal of the mucosa covering the teeth, provided this is undertaken before apical root closure. High rates of success were also obtained for mandibular second molars by Kenrad et al[12] and Wellfelt and Varpio,[11] with only 1 failed case out of 32. In contrast, Magnusson and Kjellberg[15] reported 5 failures (1 in the maxilla and 4 in the mandible) out of 17 treated molars.

Surgical uprighting was found to have a good prognosis and minimal post-operative discomfort, even if complications can occur.[13,19-21,29-33] Boynton[31] reported that surgical uprighting is a safe and predictable method for treating unerupted second molars with excellent long-term results, although it can result in root fracture and pulp necrosis. Dessner[32] detected no loss of pulp vitality among 34 treated second molars and stated that the formation of secondary dentine meant that the risks of pulp necrosis and long-term periapical pathologies were minimal with these procedures. Because a loss of vitality is most likely to occur in teeth with divergent roots, such divergence can be considered a contraindication to the surgical displacement of molars.

Surgical repositioning was reported to have an increased risk of complications and a worse prognosis,[13,19,29-32] because bodily tooth movement and fully formed roots increase the risk of damage to the root vascular pedicle and make it more difficult to move a molar. For these reasons, Peskin and Graber[29] assumed that it would be easier to perform surgical repositioning when about half or two-thirds of the molar roots have formed. However, if surgical repositioning represents the only treatment option, it can still be carried out, even in the presence of completely structured roots, because endodontic treatment may be applied if pulp necrosis were to occur.[29]

Regarding the association of third molar extraction with surgical uprighting or repositioning, the present authors agree with others[11,33,34] who have argued that third molar extraction, although is useful to obtain more space for luxation, is not always necessary. The

opposite opinion was expressed by other authors[19,21] who suggested prophylactic extraction of third molars in all cases of surgical uprighting or repositioning of second molars owing to the high predictability of these methods in second molar retrieval and because third molars are unlikely to erupt in the correct position. A more cautious approach is to postpone extracting the third molar until the repositioned second molar appears to be sufficiently stable; in this way the third molar may still be used to replace the second molar if it cannot be maintained, such as in the case of root fracture caused by luxation.[33]

Unerupted molar extraction was performed with a percentage (13.7%) lower than that reported by Valmaseda-Castellón et al[9] (28%) and much lower than that reported by Palma et al[10] (65.7%), because in the present study this approach was adopted only in view of the treatment of eruption disorders. In the replacement of the extracted mesial molar with the distal tooth into the correct occlusion, the positive outcome in all 9 first molars and in 8 out of 13 second molars disagrees with other data in the literature.

Magnusson and Kjellberg[15] reported that extracting the second molar and waiting for replacement by the third molar had the highest failure rate among all therapeutic alternatives, because only a few third molars erupted and almost all of them were poorly positioned. Therefore, those authors recommended informing the patient about the possibility of a poor outcome.

The probability of success of this modality is higher when the third molar bud is in the "full crown" stage, and it is not recommended when the root bifurcation is already present,[35-37] Treatment success is adversely affected by a long time interval between second molar extraction and third molar eruption, which increases the risk of the antagonist being extruded and mesial inclination of the third molar.[11]

Finally, the choice to transplant the third molar bud into the second molar postextraction socket should be made after the patient refuses to receive orthodontic treatment, because it is less reliable than other treatments owing to the high risk of injury to the periodontal ligament and pulp necrosis of the transplanted tooth, especially in adults and in case of closed apices.[9,19] Valmaseda-Castellón et al[9] carried out this kind of treatment only after uprighting failure of the second molar.

Third molar extraction as the only therapy in second molar retention, used in 8 cases in the present study with only 1 failure, was not taken into account by Shpack et al,[17] whereas Wellfelt and Varpio[11] experienced 5 failures out of 15 cases, Magnusson and Kjellberg[15] had 12 failures out of 21 cases, and Kenrad et al[12] achieved only 9 positive results out of 27 cases (33%). In particular, the latter authors recommended third molar extraction in cases where the space reduction for second molar eruption was diagnosed early. Instead a higher rate of success (83%) was observed by Salentjin et al[38] in 20 patients, with 19 positive results out of 23 impacted maxillary second molars due to palatally positioned overlying third molars, with more rapid resolution when treatment was performed at the age of 11-14 years before the mean eruption age.

CONCLUSIONS

Failure of eruption of the first and second permanent molars is infrequent but of considerable clinical interest owing to the fundamental role that these teeth play in ensuring correct dentoskeletal development. The present study clearly demonstrates that an early diagnosis results in a better outcome regardless of the treatment used, with the number of cases with a positive outcome being highest in younger patients.

The treatment should always be individualized based on an accurate preliminary study of all anatomic, topographic, and functional features as well as of the patient's age, needs, and expectations, although in complex cases it is also difficult to define the optimal treatment result. Therefore, all procedures should be started only after a detailed discussion with the patient and his or her parents about treatment modalities, prognosis, and alternatives, as well as after a comprehensive informed consent form is signed.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajodo.2018.09.020.

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