Ectopic Eruption of the Maxillary First Permanent Molar:
Rate and Predictive Factors of Self-Correction
and
Survey of Specialists' Attitudes Regarding Intervention

by

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for the degree of Master in Science of Pediatric Dentistry

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Abstract

**Purpose:** To retrospectively assess the incidence and predictive factors for self-correction of ectopic eruption of maxillary permanent first molars (EE) and the prevailing attitudes amongst surveyed specialists regarding intervention in cases of EE.

**Methods:** Charts of patients diagnosed with EE were assessed for predictive clinical and radiographic factors. An online survey was sent to pediatric dentists and orthodontists.

**Results:** The rate of self-correction was 71%. One third of self-corrections occurred after age 9. Increased amount of impaction ($r(43)=0.59$, $p<.001$) and degree of resorption ($r(57)=0.41$, $p=.001$) were positively correlated with irreversibility. Orthodontists estimated the spontaneous self-correction rate to be lower ($t(1178)=19.2$, $p<.001$) than pediatric dentists.

**Conclusions:** One third of self-corrections occurred after 9 years of age and delaying treatment of EE may be a viable option when uncertain of the outcome. Reliable predictive factors of irreversibility of EE were identified. Differences exist between pediatric dentists and orthodontists regarding management of EE.
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Teta Laura, you waited for me to come back. Je t’aime. Tu seras toujours dans mon coeur. I will miss you.
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Ectopic Eruption of the First Permanent Molar

1 Literature review

1.1 Definition

For the purposes of this investigation, ectopic eruption of the maxillary first permanent molar (EE) is defined as a local disturbance characterized by a mesial path of eruption causing the permanent tooth to be locked under the distal undercut of the second primary molar. Other paths of ectopic eruption can be buccal or lingual. This phenomenon causes various degrees of resorption of the roots of the primary tooth. Ectopic eruption of the first permanent molar may occur unilaterally or bilaterally in the maxilla or in the mandible (Young, 1957).

1.2 Prevalence

Ectopic eruption of the maxillary first permanent molar has a prevalence that ranges between 0.75 to 4.3% (Table 1). It is increased by four-fold in persons with cleft lip and palate (Carr & Mink, 1965). A higher prevalence, 19.8%, has been reported in siblings (Kurol & Bjerkl, 1982a). Some authors report a higher incidence in males (Bjerkl & Kurol, 1981; Young, 1957), while others found no statistically significant difference between sexes (Chintakanon & Boonpinon, 1998; Kimmel, Gellin, Bohannan, & Kaplan, 1982; Pulver, 1968).
Table 1. Reported prevalence of ectopic eruption of the first permanent molar

<table>
<thead>
<tr>
<th>Study Primary Author, Year</th>
<th>Sample size</th>
<th>Number of children with EE n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheyne, 1947</td>
<td>500</td>
<td>9 (1.8)</td>
</tr>
<tr>
<td>Young, 1957</td>
<td>1619</td>
<td>52 (3.2)</td>
</tr>
<tr>
<td>O’Meara, 1961</td>
<td>315</td>
<td>6 (2.0)</td>
</tr>
<tr>
<td>Pulver, 1968</td>
<td>831</td>
<td>26 (3.1)</td>
</tr>
<tr>
<td>Bjerklin, 1981</td>
<td>2903</td>
<td>126 (4.3)</td>
</tr>
<tr>
<td>Kimmel, 1982</td>
<td>5277</td>
<td>202 (3.8)</td>
</tr>
<tr>
<td>Canut, 1983</td>
<td>800</td>
<td>26 (3.3)</td>
</tr>
<tr>
<td>Chintakanon, 1998</td>
<td>3612</td>
<td>27 (0.8)</td>
</tr>
<tr>
<td>Barberia-Leache, 2005</td>
<td>509</td>
<td>22 (4.3)</td>
</tr>
</tbody>
</table>

1.3 Etiology

The causes of ectopic eruption are multifactorial, including a genetic component and local factors.

The reported increased prevalence in siblings suggests a genetic component. In fact, a recessive inheritance pattern with reduced penetrance in girls has been suggested as a mode of inheritance (Kurol & Bjerklin, 1982a).

Chapman (1922) stated that, for ectopic eruption to occur, the forward movement of the first permanent molar must be in excess of the downward movement. He suggests one or a combination of three etiological factors: 1) the lack of forward movement of all deciduous teeth and bone containing them, 2) the first permanent molar having moved forward prematurely and 3) the early eruption of the first permanent molar. O’Meara (1961) stated that amongst the multiple factors involved, the major one was insufficient intercuspid and anteroposterior growth of the jaws.
Other proposed factors for ectopic eruptions are: lack of bony growth in the angle of the tuberosity region at the right time (Cheyne & Wessels, 1947); larger than normal mean sizes of all maxillary permanent and primary teeth, larger affected first permanent molars and second primary molars, smaller maxilla, posterior position of the maxilla in relation to the cranial base, delayed calcification of some affected first permanent molars and abnormal angulation of eruption, which was more pronounced in the irreversible type (Pulver, 1968). Another study of 129 children, found only two of the previous factors associated with irreversible ectopic eruption of the maxillary first permanent molar: significantly larger permanent molars and a more pronounced angle of eruption. A tendency for a shorter arch length is mentioned as a factor for irreversibility but was not statistically significant (Bjerklind & Kurol, 1983). Chintakanon and Boonpinon reported that important etiological factors were the eruption path of the permanent molars and the size of the mandibular second primary molars. The authors investigated whether the presence of high interproximal carious lesion reduces the prevalence of ectopic eruption and found no correlation (Chintakanon & Boonpinon, 1998). Harrison & Michal (1984) reported that inadequate placement of a stainless steel crown on the second primary molar is an iatrogenic factor of ectopic eruption of first permanent molars. Once the crown is replaced with a properly adapted one, the situation usually self-corrects.

1.4 Diagnosis

Early diagnosis of ectopic eruption can be made in children between five and seven years old on a periapical or bitewing radiograph when the first permanent molar is positioned more superiorly and mesially. Later in the eruption process, signs of resorption of the second primary molar roots are evident on radiographs. The first clinical sign of ectopic eruption is the inclination of the occlusal plane of the second primary molar. In most cases, the distal aspect will be canted occlusally which may result in an anterior open bite (Carr & Mink, 1965; Salzmann, 1957). Frequently, there will be
delayed eruption of the permanent tooth (Harrison & Michal, 1984). In some cases, as the permanent tooth erupts, the distal cusps will appear first through the gingiva (Young, 1957).

1.5 Types of ectopic eruption and their incidence

Two types of ectopic eruption were first described in a study by Young in 1957: 1) the jump type, where the ectopic molar ends up releasing its hold and erupting into occlusion; 2) the hold type where the permanent molar remains locked under the distal contour of the primary second molar until the latter exfoliates prematurely or treatment is provided. These types are also known respectively as self-correcting or reversible and irreversible or impacted. For the purpose of consistency in this text, the terms self-correction and irreversibility will be used.

In Young’s study sample of 1619 children, 52 children presented with 78 ectopic eruptions of which 47 (60%) were self-correction cases and 31 (40%) were of the irreversible type. However, the author states that ‘66% of all ectopically erupting molars jump the hurdle and erupt normally’, and is often cited for this number (Young, 1957). Two other studies report rates of self-correction consistent with Young’s results: 59% of 186 ectopically erupted teeth (Bjerklín & Kurol, 1981), and 69.4% of 36 teeth (Barbería-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005).

On the other hand, other studies report different numbers for the incidence of self-correction. In fact, one study reported that 32 of 35 (91%) ectopic eruptions found in 26 individuals were self-correcting, a much greater incidence than the above mentioned reports (Pulver, 1968). Another study of 3612 Thai students showed that only 2 (6.25%) out of 32 ectopic molars were self-correcting. However, in this study, examination was done at a later age and only clinical diagnosis was used when the molars were erupted. This study design would cause a large number of self-corrected teeth to be missed and result in the very low incidence of self-correction (Chintakanon &

In conclusion, one should note that the rate of self-correction of ectopically erupting first permanent molars has been reported with some variability (Table 2). This inconsistency may be due to a bias caused by different study designs, diagnostic methods or early implementation of treatment on self-correcting ectopic eruptions.

Table 2. Published rate of self-correction of ectopically erupting first permanent molars

<table>
<thead>
<tr>
<th>Study Primary Author, Year</th>
<th>Number of children with EE</th>
<th>Number of ectopic molars</th>
<th>Type</th>
<th>Reversible</th>
<th>Irreversible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young, 1957</td>
<td>52</td>
<td>78</td>
<td></td>
<td>47 (60%)</td>
<td>31 (40%)</td>
</tr>
<tr>
<td>Pulver, 1968</td>
<td>26</td>
<td>35</td>
<td></td>
<td>32 (92%)</td>
<td>3 (8%)</td>
</tr>
<tr>
<td>Bjerklin, 1981</td>
<td>126</td>
<td>186</td>
<td></td>
<td>110 (59%)</td>
<td>76 (41%)</td>
</tr>
<tr>
<td>Chintakanon, 1998</td>
<td>23</td>
<td>32</td>
<td></td>
<td>2 (6%)</td>
<td>30 (94%)</td>
</tr>
<tr>
<td>Barberia-Leache, 2005</td>
<td>22</td>
<td>36</td>
<td></td>
<td>25 (69%)</td>
<td>11 (31%)</td>
</tr>
<tr>
<td>Mooney, 2007</td>
<td>28</td>
<td>NA</td>
<td></td>
<td>(50%)</td>
<td>(50%)</td>
</tr>
</tbody>
</table>

NA: not indicated

1.6 Consequences of ectopic eruption

Reversible ectopic eruption can result in various degrees of resorption of the primary second primary molar which is usually maintained until timely exfoliation. Rarely, the deciduous tooth may exfoliate early in which case a space maintainer might be indicated to preserve the space until the second bicuspid erupts. In a study of 92 self-correcting ectopic molars, adverse events occurred in only one of the resorbed primary teeth, which needed to be extracted because of an infection.
Another primary tooth exfoliated prematurely, soon after the eruption of the permanent molar. The other 90 resorbed primary teeth were maintained until normal exfoliation and served as excellent maintainers of space and function (Kurol & Bjerklin, 1982b).

Irreversible ectopic eruption results in early loss of the primary second molar before the complete eruption of the permanent first molar. If no treatment is initiated, this will lead to the mesial eruption of the first permanent molar resulting in space loss, crowding of the corresponding posterior segment and possible impaction of second premolar. Early loss of the second primary molar may occur 4 to 5 years prior to the normal exfoliation date. Malocclusion is further complicated by the overeruption of the opposing permanent molar (Yuen, Chan, & Tay, 1985). Future corrective treatment may be complicated, lengthy and costly including distalizing and uprighting of the permanent molar by use of a fixed or removable appliance and subsequent long term space maintenance.

Ectopic eruption can rarely lead to undetected caries on the partially erupted permanent first molar. Occasionally, pain can be associated with the resorbing primary tooth. Abscess formation has been reported as a consequence of ectopic eruption (Kupietzky, 2000), but it is believed to be caused by carious pulp exposure of the resorbed teeth or some other condition, for example infection of the periodontal pocket produced around the area, rather than the extensive resorption into the pulp. In fact, tertiary dentin being laid down and obliterating the pulpal exposure has been observed in these resorbed teeth (Young, 1957). Histologically, the primary second molars roots show signs of active resorption creating lacunae containing dentinoclasts, as well as areas of hard tissue deposition. This repair tissue has been interpreted as bone (Kurol & Bjerklin, 1982b).
1.7 Indication for intervention

Untreated irreversible ectopic eruption of first permanent molars may cause premature loss of the primary second molar and result in unfavorable occlusion and space deficiency for the second premolar (Harrison & Michal, 1984; Kennedy & Turley, 1987). Less frequently abscess formation and pain may occur (Kupietzky, 2000). On the other hand, if the molar is self-correcting, treatment is unnecessary. Delivering treatment when not indicated may be detrimental, cause bacterial infiltration, increase the risk of infection and accelerate the loss of the primary tooth. If an unnecessary treatment is provided, cost and time of the patient and the practitioner are exhausted (Kurol & Bjerklin, 1982b). Therefore, proper diagnosis of the type of eruption is crucial for the delivery of appropriate treatment. Unfortunately, this is a challenging task, as no definitive criteria have been established to accurately predict the outcome. However, a few authors have presented guidelines and recommendations to aid in determining when to intervene.

1.7.1 Potential predictive factors

1.7.1.1 Rotation of the permanent first molar

Two pathways of eruption have been described by Young (1957). In the first, the permanent molar erupts broadside, meaning that the whole of its mesial surface brushes along the distobuccal root and distal surface of the primary. These cases were most likely self-correcting and delaying treatment is recommended. In the second direction of eruption, the permanent molar rotates so that the mesio-buccal cusp becomes locked and the distal cusps continue to erupt. This creates a greater eruption angulation. Space loss is greater in this type and intervention was recommended (Young, 1957). Bjerklin (1983) also found that molars presenting with irreversible ectopic eruption showed a tendency to have rotated mesiopalatally.
1.7.1.2 Age and observation period

In a study conducted on 126 cases of ectopic eruption, Bjerklind and Kurol (1981) observed that in approximately 90% of cases, the type of ectopic eruption could be assessed during the child’s 7th year of life. The remaining 10% were assessed between 8 and 9 years of age. In case of doubt, the authors recommend postponing treatment for a few months (Kurol & Bjerklind, 1982b). Young stated that self-correction can occur between 6 months to 2 years after diagnosis of ectopic eruption (Young, 1957). Most authors recommend an observation period of 3 to 6 months from diagnosis before intervening (Harrison & Michal, 1984; Kennedy & Turley, 1987). On the other hand, initiating treatment early may afford a better chance for proper alignment and positioning of the permanent tooth. Far more potential harm to the primary and permanent molars is risked if clinical treatment is postponed (Harrison & Michal, 1984).

1.7.1.3 Severity of lock

Harrison and Michal (1984) classified the ectopic eruption as minimal versus severe locks (Figure 1). A minimal lock occurs when the permanent molar is impacted by half or less the width of its marginal ridge by the second primary molar. A severe lock occurs when the impaction is more than half the width of the molar’s marginal ridge. The authors indicate that treatment is warranted when severe lock is present. Severe lock warrants immediate treatment including exposure and appliance therapy to correct the problem.
Figure 1: Presentation of minimal and severe lock of ectopically erupting permanent first molars (Harrison & Michal, 1984)

Minimal lock: the ectopic permanent molar is impacted by one half or less the width of its marginal ridge

Severe lock: the permanent molar is impacted by more than one half the width of its marginal ridge

1.7.1.4 Presence of an enamel ledge

In 1987, Kennedy and Turley proposed a flow-chart to determine when to initiate treatment, based on factors such as the clinical eruption status of the permanent tooth, its change in position, the amount of ledge of the primary tooth entrapping the permanent molar, the mobility of the primary tooth and the presence of pain and infection (Figure 2). In these guidelines, the treatment recommended depends primarily on the amount of enamel ledge created by the root resorption of the primary molar (Kennedy & Turley, 1987). However, to date, the amount of resorption of the primary roots has not been shown to have a statistically significant relationship with a specific outcome.
Figure 2: UCLA flowchart for the management of ectopically erupting first permanent molars

(Kennedy & Turley, 1987)
1.7.1.5 Resorption

The resorptive process of the second primary molar has been described by multiple authors and different classification stages have been suggested as a predictive factor regarding outcome (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005; Cheyne & Wessels, 1947).

The resorption of the primary tooth may be minimal or extensive regardless of the type of ectopic eruption. The resorption may progress through the whole root while the permanent tooth remains in the same position and later uprights itself (Young, 1957). Sixty-four out of 92 cases of reversible ectopic eruption showed severe resorption of the second primary molar defined as approaching or encroaching the pulp; these teeth were all maintained until normal exfoliation. In most cases, the resorption is arrested once the permanent tooth erupts but rarely, continued resorption of the primary tooth has been observed (Kurol & Bjerklin, 1982b).

Chintakanon and Boonpinon (1998) looked at and found no correlation between the degree of resorption of the primary molars and the type of ectopic eruption. In a more recent study of 36 ectopically erupted molars, a grading system was used to classify the degree of resorption (Figure 3). There was a tendency for self-correction in the lowest degrees of resorption but this was not statistically significant (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005).
Figure 3: Grading of degree of resorption of ectopically erupting first permanent molars (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005)

I. Mild: resorption limited to cementum or with minimum dentin penetration

II. Moderate: resorption of the dentin without pulp exposure

III. Severe: resorption of distal root leading to pulp exposure

IV. Very severe: resorption that affects the mesial root of the primary tooth

1.7.1.6 Amount of impaction of the permanent tooth under the distal contour

The amount of impaction of the first permanent molar was described by Barberia-Leache (2005) as the distance from the area of maximum convexity of the mesial contour of the permanent tooth to a tangential plane to the distal surface of the primary tooth (perpendicular to the occlusal surface) (Figure 4). No statistical correlation between this measurement and the degree of resorption of the primary molar was found. The correlation between the amount of impaction and the outcome of the ectopic eruption was not assessed.
Figure 4: Representation of the measurement of the amount of impaction of the first permanent molar (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005)

1.7.1.7 Angulation of the permanent tooth

A more pronounced angle of eruption has been suggested as an etiologic factor for the ectopic eruption of the permanent maxillary first molar. The angle between the long axis of the first permanent molar and the occlusal plane (Figure 5) was found to be more obtuse in the irreversible type (Bjerklin & Kurol, 1983; Pulver, 1968).

Figure 5: Measurement of the angulation of the first permanent molar (Pulver, 1968)
1.7.1.8 Partial eruption in the mouth

Multiple authors agree that if the permanent tooth is partially erupted it will seldom self-correct. This usually presents as the emergence of the distal cusps and the increased angulation in the position of the permanent molar (Harrison & Michal, 1984; Kupietzky, 2000; Young, 1957).

1.7.1.9 Bilateral ectopic eruption

The presence of bilateral ectopic eruption was significantly correlated with self-correction in a study of 36 ectopic teeth (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005).

1.7.2 Conclusion

In conclusion, there is a consensus that treatment is warranted when irreversible ectopic eruption is present and unnecessary when self-correction occurs. However, a handful of studies have reported the incidence of irreversibility with variability and there is lack of evidence on which factors can be used to accurately determine the type of ectopic eruption, thus rendering the task of determining when to intervene difficult for the dentist.

1.8 Treatment

In the treatment of reversible ectopic eruption, a period of observation of 2 to 3 months intervals has been recommended (Gehm & Crespi, 1997; Harrison & Michal, 1984). The main objectives of treatment for irreversible ectopic eruption of a first permanent molar are to prevent the loss of the
second primary molar and to regain lost arch length by repositioning the first permanent molar distally. The retention of the second primary molar will allow proper space maintenance and normal eruption of the second premolar (Kennedy & Turley, 1987). Treatment varies according to the severity of the impaction as well as the maintainability of the primary second molar.

Treatment may be classified into three main categories: minimal intervention, appliance therapy with retention of the primary second molar and appliance therapy with extraction of the second primary molar (Gungor & Altay, 1998).

1.8.1 Minimal intervention

Interproximal wedging consists of creating a separation between the mesial surface of the permanent first molar and the distal surface of the second primary molar to allow the permanent molar to free itself from the undercut of the primary tooth. This can be done with an elastic separator, a brass wire or a spring and is indicated as an initial treatment or when the impaction of the permanent molar does not appear severe. These wedging techniques have many advantages: they generally minimize chair time, they do not require impressions or laboratory procedures and they do not damage the permanent teeth (Gehm & Crespi, 1997). Other minimal interventions include gingivectomy to expose of the permanent tooth and disking of the distal surface of the primary second molar.

1.8.1.1 Elastic separator

The simplest treatment consists of placing an orthodontic separating elastic between the primary second molar and the permanent first molar. Topical anesthetic may permit more comfortable placement of the elastic (Glenn, 1978). Placement with waxed floss instead of pliers may prevent
damage to the gingiva. The elastic must be replaced every 7 to 14 days until there is overcorrection of the impaction. Spontaneous loss of the separator indicates correction (Kennedy & Turley, 1987). Evidently, the tooth must have emerged somewhat from the gingiva to allow for proper positioning of the elastic.

1.8.1.2 Brass wire technique

If the permanent molar is not erupted, the brass wire technique may be used. This technique requires local anesthesia. A brass wire is threaded through the interproximal area and looped around the marginal ridge of the permanent molar. Both ends of the wire are twisted until snug and tucked into the interproximal area to avoid discomfort. The wire must encircle the contact area. A bitewing radiograph is taken to confirm the correct placement of the wire. The patient is seen at regular intervals to tighten the wire. The wire may be removed once it slips through the contact during tightening (Yaseen, Naik, & Uloopi, 2011). This technique may result in infection or early loss of the primary molar, therefore careful supervision is recommended (Kupietzky, 2000).

1.8.1.3 Helical spring

A triangular helical spring has been described as an adjunct to the elastic separator technique. It is suggested that the space created by the brass wire or the elastic separator is limited and therefore not effective. A spring composed of three helical loops in a triangular shape is thus fabricated and inserted between the permanent first molar and the second primary molar. The wedging spring should be reactivated or replaced every 3 weeks (Y. H. Kim & Park, 2005).
1.8.1.4 De-Impactor spring

This prefabricated looped wire (Arkansas Dental Products) is wedged into the interproximal area and the occlusal loop is twisted to create a separation between the primary and permanent teeth (Venn, 1985).

1.8.1.5 Surgical exposure of the permanent tooth

If the tooth is not erupted clinically, simple excision of the overlying tissue may be the treatment of choice. This can be easily done with a scalpel or electrosurgery. Harrison and Michal (1984) observed that in minimal lock cases, self-correction occurred more frequently and more quickly after surgical exposure. They also recommend surgical exposure of the first permanent molar if it is positioned very high to avoid the use of any appliance. Self-correction should be observed within 3 to 4 months, if the condition has not improved, appliances are used (Harrison & Michal, 1984).

1.8.1.6 Disking of the distal surface of the second primary molar

Distal disking of the primary molar is suggested in cases where there is severe crowding warranting future premolar extraction or when the premolars are absent. This will reduce the undercut created by the distal contour of the primary tooth and allow the permanent tooth to erupt slightly mesially.
while retaining the second primary molar as a space maintainer until future orthodontic treatment is initiated (Kennedy & Turley, 1987).

1.8.2 Appliance therapy with retention of the second primary molar

Multiple appliances have been described using anchorage on the second primary molar with a distalizing or tipping force on the permanent molar. These are indicated in cases of irreversible ectopic eruption where the tooth is partially erupted. If the tooth has not emerged, a gingivectomy is indicated prior to placement of the appliance. These appliances may increase the amount of resorption on the second primary molar because of the stress placed on the molar. Often the second primary molar is mobile and temporarily slightly extruded during treatment. It usually self-correction as soon as the appliance is removed.

1.8.2.1 Humphrey-type appliance

The Humphrey appliance consists of an orthodontic band fitted on the second primary molar with a distal extending free arm engaging the occlusal pit of the first permanent molar to create a distal movement. The original appliance often necessitated a small cavity preparation in the occlusal pit of the permanent tooth to prevent the arm from slipping (Humphrey, 1962). In view of better bonding techniques nowadays, it is preferred to activate the distalizing arm against a bonded button or resin stop on the occlusal surface of the permanent tooth (Gehm & Crespi, 1997). Activation of this appliance is done every 3 to 4 weeks. The appliance may be designed in such a way that the spring assembly can be removed for adjustments without removing the band. The advantage of this type of appliance is that it is fast acting and can be easily removed once the EE is corrected. A disadvantage is that because of lack of anchorage, the first and second molars may move mesially and arch length may be lost (Kurol & Bjerklin, 1986). Also, this appliance allows only anterio-posterior movement.
As the permanent molar moves distally, the primary tooth may cant occlusally (Gungor & Altay, 1998). To avoid relapse, it is important to make sure the permanent tooth has erupted sufficiently to clear the resorbed area before removing this appliance.

Many modifications can be made to this appliance. Helical loops may be incorporated to allow for vertical as well as buccal and lingual movement (Kennedy & Turley, 1987). The helical wires may be doubled as in the Gropers appliance (Groper, 1992).

1.8.2.2 Halterman appliance

This appliance consists of a band placed on the second primary molar with a large diameter soft wire with a distal hook placed 2 mm distal to the clinical crown of the permanent tooth. A tight loop chained elastic is placed between the distal hook and a button bonded to the permanent molar. The elastic chain creates a distal force on the permanent tooth. Follow-up is recommended every 3 weeks. If more correction is needed, the tension on the elastic may be increased or the appliance may be removed and the wire repositioned more distally with a three-prong plier. The appliance may be removed once the impaction of the first permanent molar is corrected (Halterman, 1982).

1.8.2.3 Multi loop unilateral bonded appliance

This modified bilateral Halterman appliance can be used to treat bilateral ectopic eruption of the first permanent molar. The bands are placed on the first primary molars, and joined by a transpalatal bar with an acrylic button for stabilization. Bilateral distal extensions with hooks are fabricated on which chain elastics are placed on buttons bonded to the permanent teeth and to the distal hooks. An advantage of this appliance is that it does not apply any force on the primary second molars, which
may have severe root resorption. This appliance may also be used to regain space if the second primary molar is lost prematurely (Weinberger, 1992).

1.8.3 Extraction of the second primary molars and space regaining

In cases where the second primary molars have been lost prematurely a space regainer is then necessary to distalize the first permanent molar once it is erupted. Extraction and space regaining are also recommended in cases of irreversible ectopic eruption where there is severe resorption, mobility, pain or infection (Chapman, 1923).

1.8.3.1 Removable appliances

A removable appliance with adams clasps for retention and fingersprings to distalize the first permanent molars can be used. The advantage of this appliance is that it permits better oral hygiene. As with all removable appliances, the main issue is that patient compliance is necessary. The use of this appliance is recommended in unilateral cases only because in bilateral cases the reciprocal forces from the activated springs may dislodge it (Kurol & Bjerklind, 1986). This issue can be remedied by the addition of Adams clasps on the central incisors or a Hawley bow to increase anchorage (Kennedy & Turley, 1987). An anterior bite plane may be required in cases where there is severe space loss and tipping of the first permanent molar.

1.8.3.2 Cervical Headgear

Extra-oral traction is an effective way to distalize molars, especially in bilateral situations. Cervical headgear has been suggested as a treatment for space regaining and to promote posterior growth of the maxilla (Kurol & Bjerklind, 1984). It has been proposed that ectopic eruption may result from a
smaller maxilla. Therefore further development and growth of the posterior segments is of importance, and may affect the longer term treatment results.

In a study of 46 children, cervical traction applied for an average of 9 months in children with irreversible ectopic eruption resulted in uprighting of the maxillary first permanent molar to good occlusion. This treatment was successful in 70% of the children, where sufficient space was created for the second premolar. Poor cooperation was the main reason for failure in the remainder of the sample. The cervical traction also led to decreased sagittal maxillary growth and to proclination of the maxillary incisors. Cervical traction gave the best results in older children, whose second premolars were near eruption or were erupting at the end of treatment (Kurol & Bjerklin, 1984). A proper cephalometric analysis is recommended prior to the treatment as it may inhibit growth of the maxilla. Cervical headgear should be avoided in patients who show a tendency for mandibular prognathism (Kurol & Bjerklin, 1984).

Cervical traction has been a controversial treatment option. In fact, patients presenting with ectopic eruption of the first permanent molar have been shown to have a more retrusive maxilla and a tendency to dolicocephaly and shorter anterior cranial base (Pulver, 1968). These morphogenetic characteristics are usually a contraindication to use extra-oral forces to move the affected molars distally. Advocates of this theory recommend the use of removable appliances or plates with horizontal reciprocal action (Canut & Raga, 1983; Pulver, 1968). However, a long-term follow-up of 45 children treated with extra-oral cervical traction was done and a discriminant analysis showed that all possible negative effects (increased proclination of the incisors, distal tipping of the normally erupting first permanent molars in unilateral cases and reduction of maxillary growth) had been eliminated. Hence, cervical traction treatment may be an adequate treatment if the patient has no other malocclusion (Bjerklin, Gleerup, & Kurol, 1995).
1.8.3.3 Space maintenance

Space maintenance is necessary after any of the above mentioned active treatments until the eruption of the second premolar. A band and loop appliance or a transpalatal arch are appropriate space maintainers for this purpose (Kennedy & Turley, 1987).

1.8.4 Management of ectopically erupting mandibular molars

Ectopic eruption of the first permanent molars is less frequent in the mandible than in the maxillary arch (Young, 1957). Distal movement of the permanent first molar is more challenging because of the reduced anchorage available from mandibular anterior teeth and the presence of denser bone in the mandible. A major challenge in the treatment of this condition is to avoid proclination of the lower incisors and intercanine width expansion (Kennedy, 2008).

Only a few case reports have described treatment of mandibular ectopic eruption of the first permanent molars in the mixed dentition. The same appliances described for the maxilla may be adapted for use in the mandibular arch. Treatment duration may be longer due to the denser bone (Kennedy, 2008; Yaseen, Naik, & Uloopi, 2011).

1.9 Associated anomalies

Children with EE are more likely to have one associated dental anomaly (Mooney, Morgan, Rodd, & North, 2007). Significantly more frequent anomalies associated with EE were the infraocclusion of primary molars (Baccetti, 1998; Bjerklin, Kurol, & Valentin, 1992) and cleft lip and palate (Mooney, Morgan, Rodd, & North, 2007). EE has also been associated with agenesis of the second
premolars (Baccetti, 1998; Pulver, 1968), reduced size of maxillary lateral incisors, enamel hypoplasia (Baccetti, 1998) and supernumerary teeth (Pulver, 1968). Additionally, ectopic eruption of the permanent canines has been associated with the ectopic eruption of the first permanent molars (Bjerklin, Kurol, & Valentin, 1992).

1.10 Survey

Studying healthcare professionals attitudes is essential as they play a key role in the rapidly changing public health system (Kellerman & Herold, 2001). This was traditionally done through postal surveys. In the past two decades, web-based health-related studies, including online survey studies, have increased exponentially (Cantrell & Lupinacci, 2007).

1.10.1 Advantages of online surveys

Survey research through online data collection is advantageous for researchers and participants. Researchers can benefit from online data collection because it is less expensive, a larger pool of participants may be reached without geographical limitations, data collection time is decreased, methodological control and efficiency of data entry and analysis are increased and it is possible to follow-up with participants (Ahern, 2005). Advantages for study participants include increased anonymity, ability to provide information at their own pace, increased sense of control, increased willingness to participate because it is a novel approach, convenience and ease of use (Ahern, 2005; Schleyer & Forrest, 2000). Additionally, the possibility of integrating better quality images, for example radiographs, and sound can produce more intuitive and rich context for research opportunities (Duffy, 2002; Schleyer & Forrest, 2000). It can also prevent erroneous answers by prohibiting multiple or unanswered responses (Schleyer & Forrest, 2000).
1.10.2 Disadvantages of online surveys

Despite the many advantages of online surveys, they may pose unique methodological problems. The lack of control of the testing environment by the researcher may result in extraneous variables that might bias the response in studies that require accurate timing or involve interpersonal interactions (Ahern, 2005; Eaton & Struthers, 2002). Also, differences in the respondents’ computer equipment can affect the appearance of the questionnaire or the ease of using it; these variations include the configuration of the user’s screen resolution, internet connection speed, memory resources and software applications (Leece et al., 2004). The main challenge with internet survey’s validity is participant selection bias. In fact, non-response bias is essential to evaluate the representativeness of a survey and may reduce its validity if there are significant differences between participants and non-participants. Typically, for an online survey, the sample pool will include people who are internet literate and who have access to a computer. This may result in some age and gender discrepancy. A high response rate is therefore ideal to reduce participant selection bias. Additionally, determining the number of survey recipients is difficult due to the possibility of faulty email addresses, the email not being received or read by the recipient. This creates an inherent problem in accurately determining the actual response rate of a web-based survey. This inaccuracy may be reduced by a higher number of responses. In some studies comparing internet to traditional paper surveys, relatively lower response rates were reported in web-based surveys (Leece et al., 2004); although numerous researchers across disciplines found there were no differences in data collected from internet research compared to paper and pencil data (Ahern, 2005; Barry, 2001; Parashos, Morgan, & Messer, 2005; Schleyer & Forrest, 2000).
1.10.3 Response rate

A response rate can be generally defined as the proportion of individuals selected into a sample who are eligible and ultimately participate in the survey. A high response rate from any sample is essential for the data to be representative of the entire population (Tambor et al., 1993), as it can reduce the effects of nonresponse bias caused by socio-demographic and behavioral differences between responders and non-responders (Parashos, Morgan, & Messer, 2005). There is no scientifically proven minimally acceptable response rate. A response rate of 60% has been used as a threshold of acceptability, but it is just a “rule of thumb” (Johnson & Wislar, 2012). Past surveys of health professions reported response rates ranging from nine to 94%.

Recently, empirical assessments have concluded that the response rate of a survey may not be as strongly correlated with the quality or the representativeness of the survey as has been previously thought (Keeter, Miller, Kohut, Groves, & Presser, 2000). In fact, if a survey has a high response rate but its non-respondents are very different from the respondents, this might produce more biased results than a survey with lower response rate where there are little differences between respondents and non-respondents. On the other hand, substantial differences between respondents and non-respondents have been described even with a moderately high response rate (60-70%) (Johnson & Wislar, 2012). One can argue that a healthcare professional survey may differ from a general population survey by the fact that the group surveyed may have similar demographics (Tambor et al., 1993). Increasing response rates may not reduce non-respondent bias if the additional respondents are more similar to the early respondents than the remaining non-respondents. In a study comparing early late and non-respondent to a physician’s survey, little difference in demographic factors was found. This may be explained by the homogeneity of the group surveyed.
The existing variations among physicians may not be related to the willingness to respond to a survey (Kellerman & Herold, 2001).

Effective strategies to increase response rates include shorter questionnaires, ease of access and prepaid monetary incentives (Kellerman & Herold, 2001; Tambor et al., 1993). Sending follow-up reminders substantially increases response rates (Braithwaite, Emery, De Lusignan, & Sutton, 2003). Ease of use of the survey is very important not to deter participants away. For example, having to enter an identification number and a pin to access the questionnaire is an additional step that can discourage respondents from completing the survey. Theoretically, surveys to healthcare professionals should elicit higher response rates than those of less educated respondents. In contrast, some professionals may resist surveys that pose questions that stereotype or generalize issues or are restrictive; do not make sense to them and take too much time out of an already overburdened schedule (Kellerman & Herold, 2001). Therefore, a well-designed survey is very important.

1.11 Rationale

The rate of self-correction of ectopic eruption has been reported with a high degree of variability. The literature agrees that while self-correcting ectopic eruptions do not require any treatment, intervention is warranted in irreversible cases and may prevent early loss of the deciduous molar and concomitant space loss. Multiple guidelines and predictive factors have been reported in the literature to predict the type of ectopic eruption. However, very few of these factors have been systematically assessed. The lack of evidence-based guidelines in the diagnosis of ectopically erupting first permanent molars makes it difficult for the clinician to know when to intervene. It may also create discrepancies in treatment between clinicians thus affecting the quality of care that is provided to patients.
Chapter 2

PART I

2 Retrospective Chart Review

2.1 Objectives

• To determine the incidence of self-correction in a sample population presenting with ectopic eruption of the maxillary first permanent molar (EE) where no interceptive treatment was initiated.

• To determine the age range at which self-correction of ectopic eruption of the maxillary first permanent molar occurs.

• To assess which clinical and radiographic factors are predictive of irreversible versus self-correction of ectopic eruption of the maxillary first permanent molar.

• To assess the occurrence of adverse events in self-correcting and irreversible ectopic eruption of the first permanent molar in a population where no corrective treatment was initiated.
2.2 Materials and Methods

Cases of ectopic eruption of the first permanent molar identified between 2000 and 2012 were reviewed. All cases were obtained from a single private practice where no interceptive treatment was initiated.

2.2.1 Inclusion and exclusion criteria

The inclusion criteria were:

- Healthy children (ASA I, II)
- Diagnosis of ectopic eruption of a permanent first molar with radiograph available for diagnosis
- Minimum follow-up of two years or until the permanent tooth has reached its normal position in the occlusal plane

Cases with craniofacial anomalies, cases where no radiographs were available or cases with unknown outcome were excluded from this study.

2.2.2 Outcome

The outcomes assessed were defined as:

- Self-Correcting (SC): the ectopic maxillary first permanent molar erupted into occlusion and the primary second molar was retained with various degrees of resorption;
- Irreversible (IRR): the maxillary first permanent molar remained locked under the distal contour of the primary second molar until the latter exfoliated prematurely or extraction was performed due to signs and symptoms.
2.2.3 Data collection and analysis

Clinical predictive factors assessed were the gender, the age at diagnosis and outcome of the ectopic eruption of the maxillary first permanent molar, bilateral versus unilateral occurrence and the features of the primary occlusion (primary molar occlusion, primary canine occlusion and Baume type).

Bite-wing radiographs obtained at the time of diagnosis were scanned and printed to scale. Radiographs were analyzed by a single investigator (B.D.) for the following factors:

1) The thickness of the enamel ledge on the primary second molar (<1mm, ≥1mm) (Kennedy & Turley, 1987);

2) The severity of lock (mild: <1/2 of the marginal ridge of the permanent molar, severe: ≥1/2 of marginal ridge) (Harrison & Michal, 1984);

3) The angulation of the permanent first molar with the occlusal plane (<90°, = 90°, >90°) (Pulver, 1968);

4) The degree of resorption on the roots of the primary teeth (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005):
   - Mild: resorption limited to cementum or with minimum dentin penetration
   - Moderate: resorption of the dentin without pulp exposure
   - Severe: resorption of distal root leading to pulp exposure
   - Very severe: resorption that affects the mesial root of the primary tooth

5) The amount of impaction of the first permanent molar (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005)
   - The distance from the area of maximum convexity of the mesial contour of the
permanent tooth to a tangential plane to the distal surface of the primary tooth (0-0.9mm, 1-1.9mm, 2-2.9mm, >3mm).

Ten radiographs were randomly chosen and assessed by three calibrated raters for inter-rater reliability to determine the reproducibility of these measurements between clinicians. Additionally, the principal investigator was assessed for reliability by assessing ten radiographs at three separate times. Cronbach's Alpha coefficient was used to determine inter-rater and intra-rater reliability.

A binomal logistic regression analysis with a probit link accounting for dichotomous dependent variables was conducted to assess the correlations between each factor and the outcome. A full regression model using a logit link was used to assess the relationship between all factors, controlling for other predictive factors, and irreversible outcome. Data was analyzed using R v.2.15.3 (R Foundation for Statistical Computing, Vienna, Austria).

### 2.2.4 Sample size

A sample size was calculated to assess the number of cases necessary to detect a different rate of self-correction than the accepted rate in the literature (66%) (American Academy of Pediatric

```markdown
Using G*Power (v. 3.1):

Test: Exact - Proportion: Difference from constant (binomial test, one sample case)
Analysis: A priori: Compute required sample size
Input: Tail(s) = One
Effect size g = 0.2399998  [Calculated using an odds ratio of 4.636 from proportions P1 = 0.66 and P2 = .90, where P1 represents the accepted incidence of self-correction in the literature (66%) and P2 represents the expected incidence (90% )]
α err prob = 0.05
Desired Power (1-β err prob) = 0.9
```
Dentistry, 2009; Young, 1957). The expected rate of self-correction in this sample population where no early intervention was initiated was 90%. Sample size calculation was done using G*Power (v. 3.1) in order to detect a difference from the accepted literature in rate of self-correction of ectopic molars at 90% power and at 5% level of statistical significance.

A sample size of 25 was required for statistical significance, but to increase the power of the analysis all the cases available were included in the study.

2.2.5 Informed consent process

An information letter describing the purpose of the research, the anonymous data collection and instructions on how to withdraw from the study was mailed to parents of children who met the inclusion criteria (Appendix I). Data collection was started 2 months after the letters were sent to allow parents to opt out of study. Ethics approval was obtained from the University of Toronto Health Sciences Research Ethics Board.
2.3 Results

2.3.1 Demographics

Two cases were not included in the study. One patient had Down syndrome and the second presented with lower bilateral ectopic eruption of the first permanent molars.

A total of 66 cases of ectopic eruption of maxillary first permanent molars in 45 patients (20 males; 25 females) were identified. The occurrence of the ectopic eruption was bilateral in 21 and unilateral in 24 patients (16 right; 8 left). Right-sided unilateral ectopic eruption was more common than left-sided unilateral ectopic eruption but this was not statistically significant ($\chi^2(2, N=24)= 5.733; p =.057$). There was no significant relationship between gender and the position of the ectopic molar.

Figure 7: Distribution of location of ectopic eruption of the maxillary first permanent molar

2.3.2 Outcome

One case was further excluded from the study because of unknown outcome. Sixty-five teeth were
included in the study. The rate of self-correction of ectopic eruption (SC) of maxillary first permanent molars in this sample population where no intervention was initiated was 71% (46/65). The rate of irreversible ectopic eruption (IRR) was 29%.

2.3.3 Observation time

The average age at diagnosis of ectopic eruption was 7 years of age and there was no statistical difference between self-correcting and irreversible cases. Fifteen (33%) cases of self-corrections occurred after age 9. The average observation time between diagnosis and outcome was 1.3 years for self-corrections and 0.8 years for irreversible cases. This difference was statistically significant \((t(37.817) = 2.15, p<.03)\) (Table 3). Fifteen cases (14 SC, 1 IRR) were observed for more than 2 years from diagnosis.

Table 3. Age at diagnosis and outcome of ectopic eruption

<table>
<thead>
<tr>
<th></th>
<th>SC</th>
<th>IRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at diagnosis</td>
<td>7 (4.8-9.4)</td>
<td>6.9 (6-8.2)</td>
</tr>
<tr>
<td>Average age at outcome</td>
<td>8.4 (5.4-11.9)</td>
<td>7.7 (6.6-9.5)</td>
</tr>
<tr>
<td>Average observation time*</td>
<td>1.3 years (0-3.2)</td>
<td>0.8 years (0-2.7)</td>
</tr>
<tr>
<td>Difference between SC and IRR significant at (t(37.82)=2.15, p&lt;.03))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3.4 Inter-rater and intra-rater correlation of radiographic factors

The degree of resorption and the impaction value were the only radiographic parameters that showed a strong inter-rater correlation between 3 different clinicians. The intra-rater correlation was acceptable for all factors (Table 4).
Table 4. Inter-rater and intra-rater correlation of radiographic parameters assessed

<table>
<thead>
<tr>
<th>Radiographic parameters</th>
<th>Inter-rater correlation (3 examiners)</th>
<th>Intra-rater correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (95% CI)</td>
<td>Agreement</td>
</tr>
<tr>
<td>Degree of resorption</td>
<td>.723 **</td>
<td>strong</td>
</tr>
<tr>
<td>Amount of enamel ledge</td>
<td>.262</td>
<td>poor</td>
</tr>
<tr>
<td>Severity of lock</td>
<td>.294</td>
<td>poor</td>
</tr>
<tr>
<td>Angulation of molar</td>
<td>.364</td>
<td>fair</td>
</tr>
<tr>
<td>Amount of impaction</td>
<td>.869**</td>
<td>almost perfect</td>
</tr>
</tbody>
</table>

*The ICC was statistically significant at $p<.001$

** The ICC was statistically significant $p<.001$

2.3.5 Predictive factors of irreversible outcome

Binomial logistic regression accounting for dependent variables found that increased impaction value ($r(43)=0.59$, $p<.001$), severe lock ($r(43)=0.53$, $p=.001$), degree of resorption of the primary second molar ($r(57)=0.41$, $p=.001$) and bilateral occurrence ($r(63)= 0.26$, $p=.03$) were positively correlated with irreversibility.

A regression model accounting for all predictive factors was positive for males, bilateral occurrence, partial eruption and severe lock as predictors of irreversible outcome (Table 5).
Table 5. Multiple regression analysis of all predictive factors for irreversible outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Z</th>
<th>P</th>
<th>95% CI for B</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.10</td>
<td>1.35</td>
<td>-0.81</td>
<td>0.416</td>
<td>-3.75 to 1.54</td>
<td>--</td>
</tr>
<tr>
<td>Male</td>
<td>2.83</td>
<td>1.26</td>
<td>2.24</td>
<td>0.025*</td>
<td>0.36 to 5.31</td>
<td>17.01</td>
</tr>
<tr>
<td>Bilateral</td>
<td>2.37</td>
<td>1.40</td>
<td>1.69</td>
<td>0.091</td>
<td>-0.37 to 5.11</td>
<td>10.69</td>
</tr>
<tr>
<td>Partial Eruption</td>
<td>-1.83</td>
<td>1.14</td>
<td>-1.61</td>
<td>0.107</td>
<td>-3.95 to 0.29</td>
<td>0.16</td>
</tr>
<tr>
<td>Severe Lock</td>
<td>2.34</td>
<td>1.16</td>
<td>2.02</td>
<td>0.042*</td>
<td>0.06 to 4.61</td>
<td>10.38</td>
</tr>
</tbody>
</table>

*Significant at p<.05

A second regression analysis was performed excluding factors found to be unreliable in the inter-rater reliability correlation test (e.g. enamel ledge, angulation and lock). The model was positive for males, impaction value and bilateral occurrence as predictors of irreversible outcome (Table 6).

Table 6. Multiple regression analysis of select reliable predictive factors for irreversible outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Z</th>
<th>P</th>
<th>95% CI for B</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-12.62</td>
<td>6.22</td>
<td>-2.03</td>
<td>0.04*</td>
<td>-24.81 to -0.43</td>
<td>--</td>
</tr>
<tr>
<td>Male</td>
<td>4.23</td>
<td>2.20</td>
<td>1.93</td>
<td>0.05</td>
<td>0.08 to 8.54</td>
<td>66.67</td>
</tr>
<tr>
<td>Bilateral</td>
<td>4.97</td>
<td>2.80</td>
<td>1.77</td>
<td>0.08</td>
<td>-0.52 to 10.46</td>
<td>144.03</td>
</tr>
<tr>
<td>Amount of impaction</td>
<td>5.81</td>
<td>2.91</td>
<td>2.00</td>
<td>0.046*</td>
<td>0.11 to 11.5</td>
<td>333.62</td>
</tr>
</tbody>
</table>

*Significant at p<.05

2.3.6 Adverse events

In the irreversible outcome group (n = 19), infection was observed in 2 cases (11%) and space loss was observed in 18 cases (95%). The estimated average space loss was approximately 3.7mm (0 to 7.7). There were statistically significant negative correlations between age of outcome and space loss (r(43)=-0.29, p=.01), indicating that the earlier the irreversible outcome occurred, the greater the space loss. However this correlation was low. In the self-correcting group, 5 primary second
molars (11%) were extracted after the eruption of the permanent first molar. None of the self-correcting cases required distalization due to space loss.

In the irreversible outcome group, 9 primary teeth necessitated extraction. Seven space maintainers were placed and 4 space regainers. Three cases required no treatment, as the space loss was minimal or the permanent successor was not present and space closure was intended. Three cases were referred to an orthodontist because of other anomalies or malocclusion.

2.3.7 Associated anomalies

Five cases of EE presented with agenesis of one or multiple second premolars.

2.4 Discussion

This retrospective chart review was done in a single private office where treatment of ectopic eruption of the first permanent molar was initiated only when the patient presented with signs and symptoms, including pain, infection or mobility of the primary tooth.

Ectopic eruption of the first permanent molar was identified in 45 patients. There was no difference in occurrence between males and females. This is in agreement with multiple reports (Chintakanon & Boonpinon, 1998; Kimmel, Gellin, Bohannan, & Kaplan, 1982; Pulver, 1968). An increase in right-sided unilateral occurrence has been reported previously (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005). In this sample, a higher number of right-side ectopic eruptions was noted but the difference was not statistically significant. The unilateral to bilateral occurrence ratio was similar in this population which is in accord with one study (Bjerklind & Kurol, 1981), while another report found a significant higher bilateral occurrence (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005).
The 71% rate of self-correction in this study was higher than previously reported in the majority of the published literature (Table 2) (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005; Bjerklin & Kurol, 1981; Young, 1957).

In this sample population, treatment was not initiated until the primary second molar presented with very severe resorption resulting in mobility, pain or infection or the primary tooth was lost prematurely. In some cases, the observation period was longer than 2 years. The majority of the literature recommends that treatment be initiated after an observation period of 3 to 6 months if self-correction has not occurred (Harrison & Michal, 1984; Kennedy & Turley, 1987). It has also been recommended that the type of ectopic eruption be determined during the child’s seventh year of life (Kurol & Bjerklin, 1982a). In this sample population, one third of the self-corrections occurred after a 2 year observation period and after 9 years of age. Had treatment been initiated earlier, the rate of irreversible ectopic eruption would have been higher. Delaying intervention in these cases was beneficial as it avoided unnecessary treatments. Self-corrections occurring after the age of 9 may be due to the exfoliation of the first primary molar resulting in the mesial drift of the second primary molar and the freeing of the permanent first molar. This phenomenon may lead to loss of arch length, although, in this sample population, none of the self-correcting cases showed clinically significant space loss. This hypothesis could be looked at in a future prospective study. The pediatric dental practice in which this study was performed differs from the average pediatric practice as it provides orthodontic care for a large number of patients. Dentists that do not provide orthodontic services may not feel as comfortable delaying interceptive treatment.

In the self-correcting group, 5 second primary molars (11%) were lost after the eruption of the first permanent molar but prior to the time of normal exfoliation. In a study of 92 resorbed primary molars due to self-correcting ectopic eruption, only 2 (2%) were lost prematurely. It may be
hypothesized that the higher incidence in this sample may have been due to the prolonged presence of the permanent tooth against the roots of the primary teeth which increased the resorption. Nonetheless, the treatment for these teeth was minimal and consisted of space maintenance.

Intervening early in the irreversible cases may have prevented the early loss of some primary teeth and space loss in the corresponding arch. Space loss was in fact the most common adverse event occurring in all but one of irreversible cases. At the same time, the cases that presented with an increased space loss occurred earlier. In fact, increased space loss was significantly correlated with earlier age at diagnosis, shorter observation period and earlier age at outcome. This signifies that irreversible ectopic eruption may not have been prevented as it is more aggressive and occurs earlier, within the first 3 to 6 months.

Of the 19 cases of irreversible ectopic eruption, 4 required space regainers, 6 required space maintainers only and 6 required no treatment as the space loss was minimal or space closure was intended due to agenesis of the second premolar. An additional 3 cases were referred to an orthodontist due other anomalies or malocclusions. The lack of a control group renders the task of determining the advantages and disadvantages of delaying treatment versus intervening early in these cases difficult.

In summary, delaying treatment in this sample population did not cause major adverse events. In fact, only 4 cases required active distalization of the first permanent molar. This indicates that delaying intervention when unsure of the type of ectopic eruption can be a viable option and may prevent unnecessary treatment and cost.

The present study findings indicate that the higher grades of resorption are correlated with irreversible outcome. Previous studies found a non-statistically significant tendency for self-
correction in the lowest grades of resorption this may be due to a smaller sample size (Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005; Chintakanon & Boonpinon, 1998).

The correlation of the amount of impaction with the outcome had not been assessed previously and had the highest correlation with irreversible outcome. This radiographic parameter was also found to be a reliable measure between different clinicians, therefore the amount of impaction seems to be a good reliable measure to aid in determining irreversibility of ectopic eruption of the maxillary first permanent molar.

Predictive measurements previously reported in the literature were found to have poor statistical reliability. In fact the poor inter-rater reliability results for the enamel ledge measurement, the permanent tooth angulation and the severity of lock indicates clinicians’ inability to consistently reproduce these measurements. This may be due to the poor description of these measurements in the original articles, as well as the lack of standardization of radiographs. Some radiographic measurements were therefore excluded from the second regression model.

The first regression model was positive for males, partial eruption, bilateral occurrence and severe lock. Due to the assumptions of logistic regression, whereas dependent variables are eliminated, some variables were not included in this model. Additionally, severe lock showed poor inter-rater reliability. Therefore, a second regression model was done excluding the variables that showed poor inter-rater reliability and including those that showed good reliability between clinicians. This model was found to be more accurate and applicable clinically and indicated that males presenting with bilateral ectopic eruption of the maxillary first permanent molars and increased amount of impaction were more likely to have an irreversible outcome. Looking at the second multiple regression model, only the impaction value is significant on its own. Although males and bilateral are not significant, they do have a substantial impact on the fit of the model overall and were
retained by a stepwise selection algorithm. Hence, they are still contributing to the model. The multiple regression models yielded very high odds ratios. This is due to the small sample size as well as the uneven distribution of the data. Future studies with a larger sample may determine more accurate odds ratio.

The regression analyses were done assessing each tooth as an independent case. This allowed inclusion of bilateral cases where the outcome was different for each side. A higher number of cases thus increased the power of the analyses. Unfortunately, this method may have created an inherent bias towards factors that are not independent, mainly gender and bilateral cases. On the other side, the relationship between gender, unilateral or bilateral occurrence and outcome was assessed and was not found to be significant. Future analysis may involve a multilevel model approach.

The retrospective chart review was limited by the data available in the charts as well as the quality and availability of the radiographs. A future prospective cohort study looking at the amount of impaction with standardized radiographs may help in developing evidence based guidelines for the decision to initiate treatment of ectopic eruption of maxillary first permanent molars.
2.5 Conclusions

1) Self-correction of ectopic eruption of maxillary first permanent molars may occur after the age of 9 and delaying intervention can be a viable treatment option when unsure of the type of ectopic eruption.

2) Increased amount of impaction and degree of resorption were identified as reliable predictors of irreversible outcome of ectopic eruption of first permanent molars.

3) Ectopic eruption presenting bilaterally in males with an increased amount of impaction are more likely to be of the irreversible type and require earlier intervention.
CHAPTER 3

PART II

3  Online Survey of Pediatric Dentists and Orthodontists

3.1  Objective

To evaluate the prevailing attitudes of pediatric dentists and orthodontists towards intervention in cases of ectopic eruption of maxillary first permanent molars.

3.2  Materials and methods

An online survey was developed using the SurveyMonkey online tool (SurveyMonkey, Palo Alto Calif). The survey was sent to all active members of the American Academy of Pediatric Dentistry, the Canadian Academy of Pediatric Dentistry and the American Association of Orthodontists. One reminder email was sent one month after the initial email.

3.2.1  Inclusion criteria

All active members of the Canadian Academy of Pediatric Dentistry (CAPD), the American Academy of Pediatric Dentistry (AAPD) and the American Association of Orthodontists (AAO) with a valid email address were asked to participate to the survey.

3.2.2  Sample size

The sample size needed to determine if predictor variables influence the decisions of practitioners to initiate treatment of an ectopically erupting permanent molar in different clinical scenarios was
determined following the rule: \( N = 104 + k; \) where \( k \) is the number of prediction variables, assuming a medium-size relationship between the independent variables (predictors) and dependent variables (decision of treatment or observation for different cases), where \( \alpha = .05 \) and power set at 80%.

The prediction variables assessed were:

1. Gender of practitioner
2. Age of practitioner
3. Years of practice
4. Type of training
5. Setting of training
6. Primary setting of current practice
7. Specialty

The minimum sample size required was 111 practitioners for regression analysis. More practitioners were surveyed to have a better representativeness of the North American population.

3.2.3 Survey content

The survey included questions on demographics and 3 cases of ectopic eruption for dentists to review and decide on whether to intervene or observe. The first case was characterized by a bilateral occurrence of the ectopic eruption of the maxillary first permanent molar; the second case was marked by the age of the patient at diagnosis, 9 years old; and the third case presented an ectopic eruption causing minimal resorption and impaction that increased over the course of a year. The survey also comprised of general questions regarding factors used to determine if intervention is warranted in a case of ectopic eruption of the first permanent molar. Pearson’s Chi-squared test was
conducted to compare responses between orthodontists and pediatric dentists.

3.2.4 Confidentiality and informed consent

The IP addresses of all respondents were blocked to ensure confidentiality. The survey did not contain any identification cookies. A letter of introduction (Appendix III) including the study’s purpose, the survey’s description and assurance of confidentiality, prefaced the survey.

3.2.5 Data analysis

The data set was compiled by the SurveyMonkey websites and exported to a Microsoft Excel spreadsheet and was analyzed using R v.2.15.3 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics and frequency distributions were used to determine if there is a consensus among practitioners toward management of ectopic molars. Multiple regression analysis was used to determine if any factors predict the decision of a practitioner to treat or observe an ectopic eruption.

3.3 Results

The total number of respondents was 1591, specifically 950 pediatric dentists and 641 orthodontists. The respective response rate was 22% and 7%. The rate of response from pediatric dentists was significantly higher than orthodontists ($\chi^2(1, N=1591)= 801.7; p <.001$).

3.3.1 Demographics

There was a significant difference in the gender distribution of pediatric dentists and orthodontists ($\chi^2(1, N=1591)= 109; p <.001$). (Figure 8). This difference is similar to the AAPD and AAO gender
distribution (Figure 9). The CAO data was not available.

**Figure 8. Gender distribution of respondents**

![Gender distribution of respondents](image1)

**Figure 9. Gender distribution of active members of the AAPD and the AAO**

![Gender distribution of active members](image2)

(source: AAPD member statistics, March 2013; personal correspondence with AAO)

There were significantly more pediatric dentists in the 30-39 age group and significantly more orthodontists in the >60 years old group ($\chi^2(4, N=1591)= 109; p <.001$) (Figure 10). Again, there are
some similarities with the AAPD and AAO age group distribution (Figure 11).

**Figure 10. Age distribution of respondents**

![Bar chart showing age distribution of respondents categorized as Pediatric Dentists and Orthodontists.](chart10)

**Figure 11. Age distribution of active members of the AAPD and the AAO**

![Bar chart showing age distribution of active members of the AAPD and AAO](chart11)

(source: AAPD member statistics, March 2013; personal correspondence with AAO)
There was significantly more pediatric dentists than orthodontists in their first decade of practice ($\chi^2(4, N=1591)= 101.1; p < .001$) (Figure 12).

**Figure 12. Number of years that respondents have been in practice**

Pediatric dentists were more likely to have a diploma and orthodontists were more likely to have a Masters degree ($\chi^2(3, N=1591)= 250.5 ; p < .001$) (Figure 13).

**Figure 13. Type of training of respondents**

<table>
<thead>
<tr>
<th>Pediatric Dentists</th>
<th>Orthodontists</th>
</tr>
</thead>
<tbody>
<tr>
<td>74%</td>
<td>49%</td>
</tr>
<tr>
<td>15%</td>
<td>37%</td>
</tr>
<tr>
<td>11%</td>
<td>13%</td>
</tr>
</tbody>
</table>
Pediatric dentists were more likely to have trained in a combined university and hospital based program while the majority of orthodontists had a university based program ($\chi^2(3, N=1591) = 883.9; p < .001$).

**Figure 14. Type of institution where respondents received their training**

The primary activity of most respondents was in private practice (Figure 15).
There was no significant difference between the geographical distribution of pediatric dentists and orthodontists as per the districts defined by the AAPD (Figure 16, 17).
Figure 16. Geographical distribution of respondents

Pediatric dentists

- District I: Northeastern Society of Pediatric Dentistry (CT, ME, MA, NH, NY, RI, VT, NL, NS; PEI, NB, QC)
- District II: Eastern Society of Pediatric Dentistry (DE, DC, MD, NJ, PA)
- District III: Southeastern Society of Pediatric Dentistry (AL, FL, GA, KY, MS, NC, SC, TN, VA, WV, PR)
- District IV: North Central Society of Pediatric Dentistry (IL, IN, IA, OH, MI, MN, NE, ND, SD, WI; ON, MB)
- District V: Southwestern Society of Pediatric Dentistry (AR, CO, KS, LA, MO, NM, OK, TX; MX)
- District VI: Western Society of Pediatric Dentistry (AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY; AB, BC, NT, NU, SK, YT)

Orthodontists

Figure 17. Representation of geographical districts
3.3.2 Ectopic eruption cases

Figure 18. Survey case 1

A 7-year-old child presents for a recall appointment. Bilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

Figure 19. Respondents’ classification of the ectopic eruption in case 1
In case 1, significantly more orthodontists than pediatric dentists ($\chi^2(1, N=1591)= 141.9; p < .001$) elected to intervene (Figure 20).

Figure 20. Specialists decision to intervene in case 1

Figure 21. Choice of treatment modality of respondents who initiated treatment in case 1
When asked, *if this situation was unilateral, would your management be the same?*, 96% of pediatric dentists and 97% of orthodontists responded yes.

**Figure 22. Survey case 2**

A 9-year-old child presents for a recall appointment. Unilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

**Figure 23. Specialist’s classification of ectopic eruption in case 2**
There was no difference between specialists in case 2, where the ectopic eruption was diagnosed in a 9-year-old patient, most practitioners elected to intervene at the time of diagnosis.

Figure 24. Specialists’ choice of treatment modality in case 2
Figure 25. Survey case 3

A. A 7 year old child presents for a recall examination. Ectopic eruption is noted on a routine bitewing radiograph

B. The child misses his next appointment and returns 1 year later. Another bitewing is taken. The condition is still asymptomatic.

Figure 26. Specialists’ classification of the ectopic eruption in case 3A

<table>
<thead>
<tr>
<th>Pediatric dentists</th>
<th>Orthodontists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self-correcting / Reversible</td>
</tr>
<tr>
<td></td>
<td>Not self-correcting / Irreversible</td>
</tr>
<tr>
<td></td>
<td>Don't know at this time</td>
</tr>
</tbody>
</table>
In case 3A, 91% of pediatric dentists and 84% of orthodontists opted to observe and follow up in 3 to 6 months. The modality of choice of those who elected to intervene was an elastic separator or brass wire.

**Figure 27. Specialists’ classification of the ectopic eruption in case 3B**

![Pie charts showing specialists' classification of the ectopic eruption in case 3B](chart)

In case 3B, 81% of pediatric dentists and 82% of orthodontists elected to intervene.
Additional treatment modalities specified in the option *other* in all 3 cases were: disking of the distal surface of the primary second molar and use of a De-Impactor spring. Pediatric dentists also suggested referral to orthodontists.
The most important factors considered by practitioners when deciding to intervene in a case of ectopic eruption of the maxillary first permanent molar were the degree of impaction (80%), the angulation of the tooth (69%) and the presence of pain (68%).

The average self-correction rate estimated by pediatric dentists was significantly higher than that estimated by orthodontists ($t(1178)=19.2; p<.001$) (Figure 29).

**Figure 29. Estimated percentage of self-correction by survey respondents**

![Estimated percentage of self-correction by survey respondents](image)

3.4 Discussion

Amongst respondents to the survey, orthodontists estimated the rate of self-correction to be much lower than pediatric dentists. This may be explained by the fact that orthodontists will not be referred patients in which self-correction has occurred but rather they will receive referrals from general and pediatric dentists once irreversible ectopic eruption has been diagnosed and space loss has occurred. Hence they may generally experience a higher rate of irreversible ectopic eruptions in
their practice. In fact, a few orthodontists commented that they receive referrals by the patient’s treating dentist following the extraction of the primary second molar. The orthodontists’ inclination to intervene earlier in the bilateral case may be due to the assumption that the cause of the ectopic eruption is skeletal and not local. Indeed, at multiple occasions, orthodontists commented that they suspect a maxillary deficiency when presented with an ectopic eruption.

The disparity in responses between pediatric dentists and orthodontists in the first survey case and in the estimated percentage of self-correction may be the product of insufficient evidence-based guidelines on the timing of intervention in cases of ectopic eruption. The development of validated guidelines will help standardize treatment among practitioners and thus improve the quality of care provided to patients. Additionally, theses guidelines should be readily available for all dentists as many general practitioners are children’s primary care dentists.

In all three cases, the main modality of treatment chosen by the respondents who opted to intervene was the elastic separator or brass wire technique. Separation is often indicated as a first treatment option that is minimally invasive and cost efficient. (Kennedy & Turley, 1987). When separation is not successful, appliance therapy is indicated. Of interest was the choice of treatment of many clinicians who indicated disking the distal of the second primary molar as an appropriate intervention. This technique has been recommended as a temporary treatment only in patients who may need future orthodontic treatment including extractions or when the premolars are missing (Kennedy & Turley, 1987). The author could not find any reliable literature supporting this intervention.

The survey was based on diagnosing ectopic eruption from bite-wings because the radiographs used were obtained from the retrospective chart review. As well, it was intended to reproduce the presentation of ectopic eruption of the maxillary first permanent molar at the initial diagnosis. This
may have been challenging for orthodontists who usually do not use bitewing radiographs but rather panoramic radiographs for treatment planning. Although panoramic radiographs are useful for a general assessment of the supporting bone and teeth, they may not be precise enough to assess the amount of impaction in millimeters or the grading of resorption in EE cases. Orthodontists who do not take intra-oral radiographs in their office may always request bitewing radiographs from the primary care dentist if needed to make a decision on when to intervene. Future investigations may look at the precision of bitewing compared with panoramic radiographs using the radiographic measurements discussed in this study.

Clinicians usually rely on the clinical and radiographic presentation of a case to complete a proper diagnosis and treatment plan. The lack of a clinical picture of the cases presented in the survey may have rendered the task more difficult.

The response rate of a questionnaire survey is defined as the number of completed and partially completed questionnaires divided by the number of eligible sample units (Leece et al., 2004; Parashos, Morgan, & Messer, 2005). The response rate for this survey was 22% for pediatric dentists and 7% for orthodontists. The response rate was significantly higher for pediatric dentists. A possible reason for the lower response rate for orthodontists is that the initial survey invitation and the reminder email were sent via the AAO as per the AAO policy; whereas for pediatric dentists, the emails were sent directly by the investigator as per AAPD policy. Orthodontists may have overlooked the email sent by the AAO thinking it was an unsolicited bulk message. As well, the survey was sent to all active members of the AAO and the AAPD in the intention of increasing response numbers. Therefore the survey was sent to a higher number of orthodontists and this may have resulted in a higher number of missing addresses, faulty emails and returned emails which
contributed to the lower survey response of orthodontists. Additionally, orthodontists may have felt that this subject is of less interest to their practice and therefore be less inclined to respond.

The response rate for this survey was fairly low. A recent online survey of 1000 pediatric dentists and 1000 orthodontists done at the University of Toronto’s department of pediatric dentistry yielded a higher response rate for pediatric dentists (42%) and similar (7%) of orthodontists (Goldenberg, 2012). Recent surveys of pediatric dentists had response rates of 25 to 48% (Lee et al., 2012; Lopez-Cepero, Amini, Pagano, Casamassimo, & Rashid, 2013; J. M. Russo, Russo, & Guelmann, 2006). Surveys of orthodontists have had response rates ranging from 10 to 40% (Burke et al., 2012; Madhavji, Araujo, Kim, & Buschang, 2011; Slack, Swift, Rossouw, & Phillips, 2013; Yang & Kiyak, 1998). A web survey of orthodontists reported a very high response rate of 92%, which was calculated by dividing the number of respondents by the number of clinicians who accessed the link. Using the definition of response rate discussed previously, the response rate would be 3% (Huang, Becerra, Walker, & Hovell, 2006).

There may be multiple reasons for the fairly low response rate in the present survey. It has been suggested that survey response rates among health care professionals has been decreasing (McAvoy & Kaner, 1996; Wiebe, Kaczorowski, & MacKay, 2012). Some clinicians have an office policy not to participate in surveys (Wiebe, Kaczorowski, & MacKay, 2012). Additionally, the survey was sent in May and the reminder 1 month later. The survey was open until September. This time period may correspond with vacations for many practitioners and the emails may not have been read in time to respond. As well, it is difficult to assess the accuracy of the email addresses provided by the organizations and there may have been multiple faulty addresses.

Sending reminders to complete surveys has been shown to improve response rate (Braithwaite, Emery, De Lusignan, & Sutton, 2003). In fact, in the present survey, survey responses increased
once the reminder email was sent. Due to the AAO policy, only one reminder was sent to orthodontists. For consistency between both groups, only one reminder was sent to pediatric dentists. Had there been an additional email reminder, the response rate may have increased.

When compared to traditional paper methods, internet surveys have relatively lower response rates (Braithwaite, Emery, De Lusignan, & Sutton, 2003). Some clinicians may not be proficient with technology or prefer to fill out the survey at a time where they do not have access to a computer and/or internet and this may have deterred them from completing the survey.

A disadvantage of online surveys is the difficulty in controlling the sample size. In fact, some email inboxes may be full or the email may be directly placed in a junk mail folder. As well, some respondents may have previously received a survey request and declined it. In fact SurveyMonkey™ has an option to opt out of any future survey. Recipients that had previously “opted out” would have not received the survey but are unaccounted for. Additionally, some other technical difficulties with the website were reported by some respondents, where they had to subscribe to the site. This was fixed in a timely manner, but there may have been respondents that encountered this problem and decided not to complete the survey. An option with web-based surveys is to restrict to one responder per computer. This is done to avoid multiple answers from the same respondents. Unfortunately, this may pose a problem if there are multiple respondents working in the same office that attempt to complete the survey.

Due to previously reported low response rates, this survey was sent to all the active members of the AAPD (4328) and the AAO (9679) with the intention to increase the number of responses. This approach did result in a high number of responses, 1591, and increase the power of the analyses. At the same time, it might have contributed to the low response rate by increasing the chances of faulty email addresses blocked surveys and returned emails. The clinicians that responded self-selected
themselves, therefore there may be a systemic bias between respondents and non-respondents. Non-respondent bias is a major concern with any type of survey study. While it is best controlled by maximizing response rates its effect must always be considered (Braithwaite, Emery, De Lusignan, & Sutton, 2003). A high response rate is essential for the data to be considered representative of an entire population (Tambor et al., 1993). Although opinions differ as to an optimal response rate to eliminate non-response bias, the reported ideal range is between 70-80% (Parashos, Morgan, & Messer, 2005; Tambor et al., 1993). However, a high response rate may still present with non-respondent bias if there is a significant difference between respondents and non-respondents (Tambor et al., 1993) and vice-versa, a survey reporting low response rate in a population where there is little difference between non-respondents and respondents may be representative of that population (Johnson & Wislar, 2012). One can argue that a healthcare professional survey may differ from a general population survey by the fact that the group surveyed may have similar demographics (Tambor et al., 1993). The existing variations between respondents and non-respondents may not be related to the willingness to participate in the survey (Kellerman & Herold, 2001). The fairly similar responses between clinicians may be another indicator of the homogeneity of the group and may indicate that a higher response rate may have yielded similar results.

3.5 Conclusions

1) Significant differences exist between pediatric dentists and orthodontists who responded to the survey in regards to ectopic eruption of the first permanent molar.

2) Compared to pediatric dentists, orthodontists who responded to the survey estimated the rate of self-correction to be much lower than pediatric dentists.
References


Goldenberg, L. (2012). A retrospective cohort study of fixed space maintainers and a survey of their use by pediatric dentists and orthodontists. Unpublished Msc, University of Toronto, University of Toronto.


APPENDIX A. Information letter to parents

UNIVERSITY OF TORONTO
FACULTY OF DENTISTRY

Dear Parents,

We are currently doing a dental study at Dr. Paul Andrews’ office on ectopic eruption of first permanent molars. Ectopic eruption is a condition where a molar comes into the mouth at a different angle and causes damage to a baby tooth. Often, this can only be seen on x-rays and does not cause any problems to the child, but in certain cases additional treatment may be required. The purpose of our study is to identify when these teeth need to be treated by the dentist. Your child, name of child, has been previously diagnosed with ectopic eruption by Dr. Paul Andrews. For this study, a single dentist will be looking at the dental records of approximately 50 children and collecting the following information: sex, age at diagnosis of ectopic eruption and outcomes, as well as information from the dental x-rays. All the information collected will be saved as a password protected document and only the dentist performing the study will have access to it. It will be saved on an anonymous basis and the name of your child will not be kept past the end of the study, which may last up to one year.

Date
With your permission, we would like to include the data from \textit{name of child} dental file. If you do not want your child’s dental file to be accessible for this study, or if you wish to learn more about this study, please contact the office of Dr. Paul Andrews at (905) 270-4700 at any time but preferably before 2 months from date of letter. Please contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273, if you have any questions or comments about your rights as a participant in this study.

Sincerely,

Dr. Michael J. Sigal

Professor and Head, Discipline of Pediatric Dentistry

Director, Graduate Program in Pediatric Dentistry

Dr. Paul B. Andrews

Assistant Professor, Discipline of Pediatric Dentistry

Clinic Director, Graduate program in Pediatric Dentistry

Dr. Basma Dabbagh

Masters Student in Pediatric Dentistry

University of Toronto
APPENDIX B. Letter to survey recipients

Dear Doctor,

My name is Basma Dabbagh. I am currently a pediatric dental resident at the University of Toronto, Toronto, Canada. As partial fulfillment of this program, I am presently conducting a survey of pediatric dentists and orthodontists on the perceived incidence of self-correction of ectopically erupting first molars and factors that are used to determine if and when intervention is warranted. The survey consists of 3 cases of ectopically erupting molars and will require 10 minutes of your time.

Your participation in this research will help determine whether there is a consensus among professionals on when to treat ectopic molars, whether this condition is under or over treated and what the most common treatment is. The survey is available online at www.surveymonkey.com/s/EctopicEruptionOrtho.

You are assured of complete confidentiality and anonymity in completing this survey. Your responses will not be linked to your name in any way.

This research has been approved by the Research Ethics Board at The University of Toronto. If you have any questions about your rights as a participant, you may contact the ethics office at ethics.review@utoronto.ca or (416) 946-3273; or in regards to the survey itself, myself, Basma Dabbagh at basma.dabbagh@utoronto.ca.

Please ensure that your responses are received no later than June 30th, 2012. Your participation in this is greatly appreciated.
Sincerely,

Dr. Basma Dabbagh

MSc. Candidate

Pediatric Dentistry, University of Toronto
APPENDIX  C. Survey of pediatric dentists

I. Demographics

What is your gender?

☐ Male

☐ Female

What is your age group?

☐ 20-29

☐ 30-39

☐ 40-49

☐ 50-59

☐ >60

How many years have you been practicing pediatric dentistry?

☐ 0-9

☐ 10-19

☐ 20-29

☐ 30-39

☐ >40

What type of pediatric dentistry training did you receive?

☐ Masters degree (3 or more years)

☐ Certificate (2 years)

In what type of institution did you receive your pediatric dentistry training?
- Hospital-based
- University-based
- PhD
- Combined

Which of the following best describes your current primary activity?
- Private practice
- Academic
- Hospital-based
- Publicly funded clinic (e.g. dental public health/Medicaid clinic/military)
- Retired from active practice

In which district do you currently practice?

- **District I: Northeastern Society of Pediatric Dentistry**

- **District II: Eastern Society of Pediatric Dentistry**
  The Eastern Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, members in the Federal Services, and foreign countries not specifically cited.

- **District III: Southeastern Society of Pediatric Dentistry**
  The Southeastern Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina,
South Carolina, Tennessee, Virginia, West Virginia and the Commonwealth of Puerto Rico.

- **District IV**: [North Central Society of Pediatric Dentistry](#)
  
  The North Central Society of Pediatric Dentistry represents the specialty of pediatric dentistry in, Nebraska, Iowa, Minnesota, Ohio, Indiana, Michigan, North Dakota, South Dakota, Illinois, Wisconsin. And the Canadian provinces of Manitoba and Ontario.

- **District V**: [Southwestern Society of Pediatric Dentistry](#)
  
  The Southwestern Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Colorado, Kansas, Missouri, New Mexico, Oklahoma, Arkansas, Louisiana, Texas and Mexico.

- **District VI**: [Western Society of Pediatric Dentistry](#)
  

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### II. Ectopic eruption cases

**Case 1**
A 7-year-old child presents for a recall appointment. Bilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered *initiate treatment above*, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
- Extraction of second primary molar and space maintainer
- Extraction of second primary molar and space regainer
- Other, please specify: ____________________________________________________________

If the situation was unilateral, would your management be the same?
☐ Yes

☐ No, please specify:

__________________________________________________________________________

__________________________________________________________________________
A 9-year-old child presents for a recall appointment. Unilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- Observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered *initiate treatment above*, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
The child returns 6 months later and there are no changes in the position of the permanent first molar. The condition is still asymptomatic.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- Observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered initiate treatment above, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
- Extraction of second primary molar and space maintainer
○ Extraction of second primary molar and space regainer

○ Other, please specify: _____________________________________________
Case 3

A 7-year-old child presents for a recall examination. Ectopic eruption is noted on a routine bitewing radiograph.

How would you classify this ectopic eruption?

- SELF-CORRECTING / REVERSIBLE
- NOT SELF-CORRECTING / IRREVERSIBLE
- DON'T KNOW AT THIS TIME

What would you do at this time?

- OBSERVE AND FOLLOW-UP IN 3 TO 6 MONTHS
- INITIATE TREATMENT

If you answered initiate treatment above, which treatment would you be more inclined to use?

- ELASTIC SEPARATOR OR BRASS WIRE LIGATURE
- APPLIANCE THERAPY WITHOUT EXTRACTION
- EXTRACTION OF SECOND PRIMARY MOLAR AND SPACE MAINTAINER
- EXTRACTION OF SECOND PRIMARY MOLAR AND SPACE REGAINER
- OTHER, PLEASE SPECIFY: ___________________________________________
The child misses his next appointment and returns 1 year later. Another bitewing is taken.

The condition is still asymptomatic.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- Observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered initiate treatment above, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
- Extraction of second primary molar and space maintainer
- Extraction of second primary molar and space regainer
- Other, please specify: ________________________________
III. General questions

In your opinion, what is the incidence of self-correction of ectopically erupting permanent first molars?

_______%

Which factor(s) do you consider when making a decision to intervene in the ectopic eruption of a first permanent molar?

- Signs and/or symptoms of pain and/or infection of the primary tooth
- Amount of ledge of the enamel of the primary tooth
- Degree of resorption of the primary tooth
- Degree of impaction of the permanent molar (amount locked under the primary tooth)
- Angulation of the permanent molar
- Partial eruption in the mouth of the permanent molar
- Bilateral or unilateral ectopic eruption
- Age of patient

When making a decision to intervene in an ectopic eruption of a first permanent molar, please rank the 3 most important factors (1-2-3) that you consider in order of importance:

- Signs and/or symptoms of pain and/or infection of the primary tooth
- Amount of ledge of the enamel of the primary tooth
- Degree of resorption of the primary tooth
☐ Degree of impaction of the permanent molar (amount locked under the primary tooth)

☐ Angulation of the permanent molar

☐ Partial eruption in the mouth of the permanent tooth

☐ Bilateral or unilateral ectopic eruption

☐ Age of patient

Any comments are appreciated:

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

Thank you for your time!
APPENDIX D. Survey of orthodontists

Survey of Orthodontists

I. Demographics

What is your gender?

- [ ] Male
- [ ] Female

What is your age group?

- [ ] 20-29
- [ ] 30-39
- [ ] 40-49
- [ ] 50-59
- [ ] >60

How many years have you been practicing orthodontics?

- [ ] 0-9
- [ ] 10-19
- [ ] 20-29
- [ ] 30-39
- [ ] >40

What type of orthodontic training did you receive?

- [ ] Masters degree (3 or more years)
- [ ] Certificate (2 years)
In what type of institution did you receive your orthodontic training?

- Hospital-based
- University-based
- PhD
- Combined

Which of the following best describes your current primary activity?

- Private practice
- Academic
- Hospital-based
- Publicly funded clinic (e.g. dental public health/Medicaid clinic/military)
- Retired from active practice

In which district do you currently practice?

- **District I: Northeastern Society of Pediatric Dentistry**
  

- **District II: Eastern Society of Pediatric Dentistry**
  
  The Eastern Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, members in the Federal Services, and foreign countries not specifically cited.

- **District III: Southeastern Society of Pediatric Dentistry**
  
  The Southeastern Society of Pediatric Dentistry represents the specialty of pediatric
dentistry in Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia and the Commonwealth of Puerto Rico.

- **District IV:** North Central Society of Pediatric Dentistry
  
The North Central Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Nebraska, Iowa, Minnesota, Ohio, Indiana, Michigan, North Dakota, South Dakota, Illinois, Wisconsin. And the Canadian provinces of Manitoba and Ontario.

- **District V:** Southwestern Society of Pediatric Dentistry
  
The Southwestern Society of Pediatric Dentistry represents the specialty of pediatric dentistry in Colorado, Kansas, Missouri, New Mexico, Oklahoma, Arkansas, Louisiana, Texas and Mexico.

- **District VI:** Western Society of Pediatric Dentistry
  
II. Ectopic eruption cases

Case 1

A 7-year-old child presents for a recall appointment. Bilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

How would you classify this ectopic eruption?

☐ Self-correcting / Reversible

☐ Not self-correcting / Irreversible

☐ Don’t know at this time

What would you do at this time?

☐ observe and follow-up in 3 to 6 months

☐ Initiate treatment

If you answered *initiate treatment above*, which treatment would you be more inclined to use?

☐ Elastic separator or brass wire ligature

☐ Appliance therapy without extraction

☐ Extraction of second primary molar and space maintainer

☐ Extraction of second primary molar and space regainer
If the situation was unilateral, would your management be the same?

☐ Yes

☐ No, please specify:

________________________________________________________________________

_____________________________________________________________________

Case 2

A 9-year-old child presents for a recall appointment. Unilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

How would you classify this ectopic eruption?

☐ Self-correcting / Reversible

☐ Not self-correcting / Irreversible

☐ Don’t know at this time
What would you do at this time?

☐ Observe and follow-up in 3 to 6 months

☐ Initiate treatment

If you answered initiate treatment above, which treatment would you be more inclined to use?

☐ Elastic separator or brass wire ligature

☐ Appliance therapy without extraction

☐ Extraction of second primary molar and space maintainer

☐ Extraction of second primary molar and space regainer

☐ Other, please specify: __________________________________________________________

The child returns 6 months later and there are no changes in the position of the permanent first molar. The condition is still asymptomatic.

How would you classify this ectopic eruption?

☐ Self-correcting / Reversible

☐ Not self-correcting / Irreversible

☐ Don’t know at this time

What would you do at this time?
☐ Observe and follow-up in 3 to 6 months

☐ Initiate treatment

If you answered *initiate treatment above*, which treatment would you be more inclined to use?

☐ Elastic separator or brass wire ligature

☐ Appliance therapy without extraction

☐ Extraction of second primary molar and space maintainer

☐ Extraction of second primary molar and space regainer

☐ Other, please specify: __________________________________________________________
Case 3

A 7-year-old child presents for a recall examination. Ectopic eruption is noted on a routine bitewing radiograph.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- Observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered initiate treatment above, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
- Extraction of second primary molar and space maintainer
- Extraction of second primary molar and space regainer
- Other, please specify: ________________________________
The child misses his next appointment and returns 1 year later. Another bitewing is taken. The condition is still asymptomatic.

How would you classify this ectopic eruption?

- Self-correcting / Reversible
- Not self-correcting / Irreversible
- Don’t know at this time

What would you do at this time?

- Observe and follow-up in 3 to 6 months
- Initiate treatment

If you answered initiate treatment above, which treatment would you be more inclined to use?

- Elastic separator or brass wire ligature
- Appliance therapy without extraction
- Extraction of second primary molar and space maintainer
- Extraction of second primary molar and space regainer
- Other, please specify: ________________________________
III . General questions

In your opinion, what is the incidence of self-correction of ectopically erupting permanent first molars?

_______%

Which factor(s) do you consider when making a decision to intervene in the ectopic eruption of a first permanent molar?

☐ Signs and/or symptoms of pain and/or infection of the primary tooth

☐ Amount of ledge of the enamel of the primary tooth

☐ Degree of resorption of the primary tooth

☐ Degree of impaction of the permanent molar (amount locked under the primary tooth)

☐ Angulation of the permanent molar

☐ Partial eruption in the mouth of the permanent molar

☐ Bilateral or unilateral ectopic eruption

☐ Age of patient

When making a decision to intervene in an ectopic eruption of a first permanent molar, please rank the 3 most important factors (1-2-3) that you consider in order of importance:

☐ Signs and/or symptoms of pain and/or infection of the primary tooth

☐ Amount of ledge of the enamel of the primary tooth

☐ Degree of resorption of the primary tooth
☐ Degree of impaction of the permanent molar (amount locked under the primary tooth)

☐ Angulation of the permanent molar

☐ Partial eruption in the mouth of the permanent tooth

☐ Bilateral or unilateral ectopic eruption

☐ Age of patient

Any comments are appreciated:

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

Thank you for your time!
Ectopic Eruption of the Permanent First Molar:

Prevalence and Prognostic Factors of Self-Correction

and

Survey of Specialists' Attitudes Regarding Intervention

Dabbagh B.*, Sigal M, Titley K, Tompson B, Andrews P

Faculty of Dentistry, University of Toronto
Abstract

**Purpose:** This study retrospectively assessed the incidence and predictive factors for self-correction and occurrence of adverse events associated with ectopic eruption of permanent maxillary first molars, in a sample population where no corrective intervention was initiated. The study also assessed prevailing attitudes amongst surveyed pediatric dentists and orthodontists regarding indications and timing of intervention of ectopically erupting permanent maxillary first molars. **Methods:** Charts of patients diagnosed with ectopic eruption of the permanent maxillary first molar were assessed and radiographs were analyzed for predictive factors reported in the literature. Outcome was determined as self-correcting: the permanent maxillary first molar erupts into occlusion and the primary second molar is retained; or irreversible: the primary second molar is lost prior to the eruption of the permanent maxillary first molar. An online survey presenting three cases of ectopic eruption was sent to active members of the American Academy of Pediatric Dentistry, the Canadian Academy of Pediatric Dentistry and the American Association of Orthodontists. **Results:** Sixty-five ectopically erupting permanent maxillary first molars were included in the study. Forty-six (71%) self-corrected, of which one third occurred after age 9. Space loss, with an average of approximately 3 mm, occurred in 18 cases (28%), all of which were irreversible. Increased impaction magnitude ($r(43)=0.59$, $P<.001$), degree of resorption of the primary second molar ($r(57)=0.41$, $P=.001$) and bilateral occurrence ($r(63)=0.26$, $P=.03$) were positively correlated with irreversibility. Multiple regression was positive for males, increased impaction magnitude and bilateral occurrence as predictors of irreversible outcome. Nine hundred and fifty pediatric dentists and 642 orthodontists responded to the survey. Orthodontists initiated treatment more frequently than pediatric dentists in a case of bilateral ectopic eruption ($x^2(1, N=1178)=141.9$, $P=.001$) and estimated the rate of spontaneous self-correction to be much lower ($t(1178)=19.2$, $P<.001$).

**Conclusion:** Spontaneous self-correction occurred in 71% of cases. One third of self-corrections occurred after 9 years of age and delaying treatment of ectopic eruption of permanent maxillary first molars may be a viable option when uncertain of the outcome. Increased impaction and degree of resorption appear to be reliable measures to predict irreversible outcome. Ectopic eruption of first permanent molars presenting
bilaterally, in males, with increased impaction magnitude are more likely to be irreversible and require early intervention.

**Introduction**

Ectopic eruption of the first permanent molar is defined as a local eruption disturbance characterized by the permanent tooth being locked under the distal contour of the second primary molar\(^1\). Ectopic eruption can give rise to various degrees of resorption of the primary teeth. Two types of ectopic eruption of the first permanent molar have been described: 1) *self-correcting*, where the ectopic molar unlocks from under the second primary molar and erupts into occlusion; 2) *irreversible*, where the permanent molar remains locked under the distal contour of the primary second molar until the latter exfoliates prematurely or treatment is provided\(^1\). Interceptive orthodontic treatment can redirect the eruption path of the first permanent molar and allow it to erupt into occlusion while maintaining the resorbed second primary molar. If interceptive treatment is not provided in irreversible cases, the second primary molar may be lost prematurely in which case space loss, crowding of the corresponding arch segment and impaction of the second premolar may occur\(^2\). In these situations, future corrective treatment will be required, consisting of distalization and uprighting the first permanent molar, which may be lengthy and complicated\(^2\).

The rate of self-correction of ectopic eruption of permanent first molars reported in the literature ranges between 59% to 69%\(^1,3,4\). Two articles have reported a self-correction rate outside that range of 91%\(^5\) and 6%\(^6\). These inconsistencies may be due to variations in study designs, diagnostic methods employed or early implementation of treatment on what could in fact be self-correcting ectopic eruption cases.

In the absence of clinical symptoms, determining if the ectopic eruption of a first permanent molar will self-correct or remain impacted and subsequently need intervention can be a challenge. Various criteria to aid in assessing the type of ectopic eruption have been reported in the literature which can be used by the practitioner to determine when and if intervention is necessary. Clinical factors that have been reported included bilateral occurrence, age, and partial eruption of the first permanent molar. Bilateral occurrence of
ectopic eruption of the first permanent molar was significantly correlated with self-correction. Bjerklin and Kurol stated that in approximately 90% of cases, the type of ectopic eruption could be assessed during the child’s 7th year of life. Additionally, partial eruption of the crown in the mouth has been cited as a poor prognostic factor for self-correction.

The ectopic eruption of first permanent molars is usually diagnosed on routine bitewing radiographs. Some authors have suggested radiographic factors which could indicate that intervention is warranted. Harrison and Michal classified ectopic eruption as minimal versus severe lock. Treatment was recommended when there was a severe lock which was defined as the impaction of half or more of the width of the marginal ridge of the first permanent molar under the second primary molar. On the other hand, Chintakanon and Boonpinon found no correlation between the severity of lock and the outcome of ectopic eruption of the first permanent molar. Pulver reported that the angle formed by the long axis of the first permanent molar and the occlusal plane was more obtuse in irreversible cases. In a flow-chart proposed by Kennedy and Turley, treatment was recommended if there was an enamel ledge of 1 mm or greater on the distal of the second primary molar once the permanent tooth was at the level of the cemento-enamel junction. In a recent study, the magnitude of impaction, defined as the distance between the maximal convexity of the permanent molar to the prolongation of the distal aspect of the primary molar, was assessed in ectopic erupting permanent first molars (Figure 1).

Figure 1. Measurement of the magnitude of impaction

The magnitude of impaction was defined as the distance between the maximal convexity of the permanent molar to the prolongation of the distal aspect of the primary molar.

(Barberia-Leache, Suarez-Clúa, & Saavedra-Ontiveros, 2005)

The authors also defined a grading system to classify the degree of resorption of second primary molars. No statistically significant correlation was found between the degree of resorption and the magnitude of
impaction. A tendency for self-correction in the lowest grades of resorption was reported but was not statistically significant. Another study also looked at the correlation between the degree of resorption and the outcome of ectopic eruption and found no statistical significance.

According to the literature, intervention is necessary when irreversible ectopic eruption is present and unnecessary when self-correction occurs. However, there is insufficient evidence regarding reported predictive factors used to determine irreversible outcome of ectopic eruption, thus rendering the task of deciding when to intervene difficult for the clinician.

The purpose of this study was to determine the incidence of self-correction in a sample population presenting with ectopic eruption of the maxillary first permanent molar where no intervention was initiated. This study also assessed if any of the factors presented by the literature could accurately predict self-correction of an ectopic maxillary first permanent molar. The second part of this study evaluated the prevailing attitudes of pediatric dentists and orthodontists towards intervention in cases of ectopic eruption of maxillary first permanent molars.

**Methods**

**Part 1: Retrospective Chart Review**

Cases of ectopic eruption of the first permanent molar identified between 2000 and 2012 were reviewed. All cases were obtained from a single private pediatric dental practice where no interceptive treatment was initiated. Cases with craniofacial anomalies, cases where no radiographs were available or cases with unknown outcome were excluded from this study. The outcomes assessed were defined as:

- **Self-Correcting (SC):** the ectopic maxillary first permanent molar erupted into occlusion and the primary second molar was retained with various degrees of root resorption;

- **Irreversible (IRR):** the maxillary first permanent molar remained locked under the distal contour of the primary second molar until the latter exfoliated prematurely or extraction was performed due to signs and symptoms.
Clinical predictive factors assessed were the gender, the age at diagnosis and outcome of the ectopic eruption of the maxillary first permanent molar, bilateral versus unilateral occurrence and the features of the primary occlusion (primary molar occlusion, primary canine occlusion and Baume arch type).

Bite-wing radiographs obtained at the time of diagnosis were scanned and printed to scale. Radiographs were analyzed by a single investigator (B.D.) for the following factors:

6) The thickness of the enamel ledge on the primary second molar $^8$ (<1mm ; ≥1mm);

7) The severity of lock $^7$: (mild: <1/2 of the marginal ridge of the permanent molar; severe ≥1/2 of marginal ridge);

8) The angulation of the permanent first molar with the occlusal plane $^5$ (<90°, = 90°, >90°);

9) The degree of resorption on the roots of the primary teeth $^3$ (mild: resorption limited to cementum or with minimum dentin penetration; moderate: resorption of the dentin without pulp exposure; severe: resorption of distal root leading to pulp exposure; very severe: resorption that affects the mesial root of the primary tooth)

10) The magnitude of impaction of the first permanent tooth measured in mm$^3$ (Figure 1).

Ten radiographs were randomly chosen and assessed by three calibrated raters for inter-rater reliability to determine the reproducibility of these measurements between clinicians. Additionally, the principal investigator was assessed for intra-rater reliability by assessing ten radiographs at three separate times. Cronbach’s Alpha coefficient was used to determine the inter-rater and intra-rater reliability. A binomial logistic regression analysis with a probit link accounting for dichotomous dependent variables was conducted to assess the correlations between each factor and the outcome. A multiple regression model using a logit link was used to assess the relationship between all factors and irreversible outcome. Data was analyzed using R v.2.15.3 (R Foundation for Statistical Computing, Vienna, Austria).

Part II: Survey

An online survey was developed using the SurveyMonkey online tool (SurveyMonkey, Palo Alto Calif). The
The survey was sent to all active members of the American Academy of Pediatric Dentistry, the Canadian Academy of Pediatric Dentistry and the American Association of Orthodontists. The survey included questions on demographics and 3 cases of ectopic eruption for dentists to review and decide on intervention or observation. The first case was characterized by a bilateral occurrence of the ectopic eruption of the maxillary first permanent molar, the second case presented an ectopic eruption in a 9 year old child, and the third case was marked by an ectopic eruption causing minimal resorption and impaction that increased over the course of a year. The survey also contained general questions regarding factors used to determine if intervention is warranted in a case of ectopic eruption of the first permanent molar. Pearson’s Chi-squared test was conducted to compare responses between orthodontists and pediatric dentists.

Results

Part I: Retrospective Chart Review

A total of 66 cases of ectopic eruption of maxillary first permanent molars in 45 patients (20 males; 25 females) were identified. The occurrence of the ectopic eruption was bilateral in 21 and unilateral in 24 patients (16 right; 8 left). There was no statistical difference between right-sided and left-sided unilateral ectopic eruption of the first permanent molar ($\chi^2(2, N=24)= 5.733; p=.057$). One tooth was excluded from the study because of unknown outcome. Sixty-five teeth were included in the study. The rate of self-correction of ectopic eruption (SC) of maxillary first permanent molars in this sample population where no intervention was initiated was 71% (46/65). The rate of irreversible ectopic eruption (IRR) was 29%.

The average age at diagnosis of ectopic eruption was 7 years of age and there was no statistical difference between self-correcting and irreversible cases. Fifteen (33%) cases of self-corrections occurred after age 9. The average time between diagnosis and outcome was 1.3 years for self-correction cases and 0.8 years for irreversible cases. This difference was statistically significant ($t(37.817) = 2.15, p<.03$). Fifteen cases (14 SC, 1 IRR) were observed for more than 2 years from diagnosis.

The degree of resorption and the impaction magnitude were the only radiographic factors that showed a strong inter-rater correlation between 3 different clinicians. The intra-rater correlation was acceptable for all
radiographic factors (Table 1).

Logistic regression analysis reported that increased impaction magnitude ($r(43)=0.59, p<.001$), severe lock ($r(43)=0.53, p=.001$), increased resorption of the primary second molar ($r(57)=0.41, p=.001$) and bilateral occurrence ($r(63)=0.26, p=.03$) were positively correlated with irreversibility.

Table 1. Inter-rater and intra-rater correlation reliability of radiographic factors

<table>
<thead>
<tr>
<th>Radiographic parameters</th>
<th>Inter-rater correlation</th>
<th>Intra-rater correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (3 examiners)</td>
<td>ICC (95% CI)</td>
</tr>
<tr>
<td></td>
<td>Agreement</td>
<td>Agreement</td>
</tr>
<tr>
<td>Degree of resorption</td>
<td>.723 ** strong</td>
<td>.940** almost perfect</td>
</tr>
<tr>
<td>Amount of enamel ledge</td>
<td>.262 poor</td>
<td>.735* strong</td>
</tr>
<tr>
<td>Severity of lock</td>
<td>.294 poor</td>
<td>.590* moderate</td>
</tr>
<tr>
<td>Angulation of molar</td>
<td>.364 fair</td>
<td>.735 ** strong</td>
</tr>
<tr>
<td>Impaction magnitude</td>
<td>.869** almost perfect</td>
<td>.869 ** almost perfect</td>
</tr>
</tbody>
</table>

*The ICC was statistically significant at $p=.001$; ** The ICC was statistically significant $p<.001$

A regression model accounting for all predictive factors was positive for males, bilateral occurrence, partial eruption and severe lock as predictors of irreversible outcome (Table 2).
### Table 2. Regression of predictive factors for irreversible outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE$</th>
<th>$Z$</th>
<th>$P$</th>
<th>95% CI for $B$</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.10</td>
<td>1.35</td>
<td>-0.81</td>
<td>.416</td>
<td>-3.75</td>
<td>1.54</td>
</tr>
<tr>
<td>Female Gender</td>
<td>-2.83</td>
<td>1.26</td>
<td>-2.24</td>
<td>.025*</td>
<td>-5.29</td>
<td>-3.36</td>
</tr>
<tr>
<td>Bilateral</td>
<td>2.37</td>
<td>1.40</td>
<td>1.69</td>
<td>.091</td>
<td>-.37</td>
<td>5.11</td>
</tr>
<tr>
<td>Partial Eruption</td>
<td>-1.83</td>
<td>1.14</td>
<td>-1.61</td>
<td>.107</td>
<td>-3.95</td>
<td>.29</td>
</tr>
<tr>
<td>Severe Lock</td>
<td>2.34</td>
<td>1.16</td>
<td>2.02</td>
<td>.042*</td>
<td>.06</td>
<td>4.61</td>
</tr>
</tbody>
</table>

*Significant at $p<.05$

A second regression analysis was performed excluding radiographic factors found to be unreliable in the inter-rater reliability correlation test (e.g. enamel ledge, angulation of the permanent molar and severity of lock). This second model was positive for males, impaction value and bilateral occurrence as predictors of irreversible outcome (Table 3).
Table 3. Regression of select reliable predictive factors for irreversible outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Z</th>
<th>P</th>
<th>Lower</th>
<th>Upper</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-12.62</td>
<td>6.22</td>
<td>-2.03</td>
<td>.04*</td>
<td>-24.81</td>
<td>-0.43</td>
<td>--</td>
</tr>
<tr>
<td>Female Gender</td>
<td>-4.23</td>
<td>2.20</td>
<td>-1.93</td>
<td>.05</td>
<td>-8.54</td>
<td>0.08</td>
<td>.01</td>
</tr>
<tr>
<td>Bilateral</td>
<td>4.97</td>
<td>2.80</td>
<td>1.77</td>
<td>.08</td>
<td>-0.52</td>
<td>10.46</td>
<td>144.03</td>
</tr>
<tr>
<td>Impaction magnitude</td>
<td>5.81</td>
<td>2.91</td>
<td>2.00</td>
<td>.046*</td>
<td>0.11</td>
<td>11.50</td>
<td>333.62</td>
</tr>
</tbody>
</table>

*Significant at $p<.05$

In the irreversible outcome group ($n = 19$), infection was observed in 2 cases (11%) and space loss was observed in 18 cases (95%). The estimated average space loss was approximately 3.7mm (0 to 7.7mm). In the self-correcting group, 5 primary second molars (11%) were extracted after the eruption of the permanent first molar.

**Part II: Survey**

The total number of respondents was 1591, specifically 950 pediatric dentists and 641 orthodontists. The respective response rate was 22% and 7%. The rate of response from pediatric dentists was significantly higher than orthodontists ($\chi^2(1, N=1591)= 801.7; p <.001$).
In case 1, presenting bilateral occurrence of ectopic eruption of the maxillary permanent first molars, significantly more orthodontists than pediatric dentists ($\chi^2(1,N=1591) = 141.9; p < .001$) elected to intervene (Figure 2).

Figure 2: Survey case 1

A 7-year-old child presents for a recall appointment. Bilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

In case 2, where unilateral ectopic eruption was diagnosed in a 9-year-old patient, most practitioners elected to intervene at the time of diagnosis regardless of the specialty (Figure 3).

Figure 3: Survey case 2

A 9-year-old child presents for a recall appointment. Unilateral ectopic eruption of the first permanent molar is observed on a routine bitewing radiograph. The condition is asymptomatic.

In the third case, where the resorption of the primary tooth increased over a period of one year, most clinicians opted to wait initially and treat once the resorption increased (Figure 4).
The most important factors considered by practitioners when deciding to intervene in a case of ectopic eruption of the maxillary first permanent molar were the degree of impaction (80%), the angulation of the tooth (69%) and the presence of pain (68%). The average self-correction rate estimated by pediatric dentists was significantly higher than orthodontists ($t(1178)=192; p<.001$) (Figure 5).

Figure 4: Survey case 3

A. A 7-year-old child presents for a recall examination. Ectopic eruption is noted on a routine bitewing radiograph

B. The child misses his next appointment and returns 1 year later. Another bitewing is taken. The condition is still asymptomatic.

Figure 5: Perceived percentage of self-correction
Discussion

The 71% rate of self-correction in this study was similar to other reports. The delay in intervention did not substantially increase the rate of self-correction. In this sample population, one third of the self-corrections occurred after a 2 year observation period and after 9 years of age. Delaying treatment in these cases did not cause any adverse effects. This indicates that delaying intervention when unsure of the type of ectopic eruption can be a viable option and may prevent unnecessary treatment and cost.

An increase in right-sided unilateral occurrence has been reported previously\(^3\). In this sample, a higher number of right-side ectopic eruptions was noted but the difference was not statistically significant. The unilateral to bilateral occurrence ratio was similar in this population which is in accord with one study\(^4\) while another report found a significant higher bilateral occurrence\(^3\).

The present study findings indicate that the higher grades of resorption are correlated with irreversible outcome. Previous studies found no correlation and this may be due to a smaller sample size. The correlation of the magnitude of impaction with the outcome had not been assessed previously and had the highest correlation with irreversible outcome. Predictive measurements previously reported in the literature were found to have poor statistical reliability. In fact the poor inter-rater reliability results for the enamel ledge measurement, the permanent tooth angulation and the severity of lock indicates clinicians’ inability to consistently reproduce these measurements and therefore they were excluded from the second regression model. This model was found to be more accurate and applicable clinically and indicated that males presenting with bilateral ectopic eruption of the maxillary first permanent molars and increased impaction magnitude were more likely to have an irreversible outcome.

The retrospective chart review was limited by the data available in the charts as well as the quality and availability of the radiographs. A future prospective cohort study looking at the impaction magnitude with standardized radiographs may help in developing evidence based guidelines in the treatment of ectopic eruption.
In the survey portion, orthodontists estimated the rate of self-correction to be much lower than pediatric dentists. Orthodontists will usually see older patients and treat the consequences of irreversible ectopic eruption once the primary second molar has been lost prematurely and therefore might experience a higher rate of irreversible ectopic eruptions in their practice. In most cases, there was a general consensus on treatment and this indicates that although there is no evidence based guidelines in the literature, most respondents will intervene in the same manner in regards to ectopic eruption. The orthodontists’ inclination to intervene in the bilateral case may be due to the assumption that the cause of the ectopic eruption is skeletal and not local. The survey had a large sample with relatively homogeneous responses. However, a weakness of the survey was the low response rate which may have resulted in self-selection bias.

Conclusions

Based on this study the following conclusions can be made:

4) Self-correction of ectopic eruption of maxillary first permanent molars may occur after the age of 9 and delaying intervention can be a viable treatment option when unsure of the type of ectopic eruption.

5) Increased impaction magnitude and degree of resorption are reliable predictors of irreversible outcome of ectopic eruption of first permanent molars.

6) Ectopic eruption of the maxillary first permanent molars presenting bilaterally, in males, with an increased amount of impaction are more likely to be of the irreversible type and require early intervention.

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