**ABSTRACT**

**Objectives:** To assess the null hypothesis that there is no difference in the rate of dental development and the occurrence of selected developmental anomalies related to shape, number, structure, and position of teeth between subjects with impacted mandibular canines and those with normally erupted canines.

**Materials and Methods:** Pretreatment records of 42 subjects diagnosed with mandibular canines impaction (impaction group: IG) were compared with those of 84 subjects serving as a control reference sample (control group: CG). Independent t-tests were used to compare mean dental ages between the groups. Intergroup differences in distribution of subjects based on the rate of dental development and occurrence of selected dental anomalies were assessed using \( \chi^2 \) tests. Odds of late, normal, and early developers and various categories of developmental anomalies between the IG and the CG were evaluated in terms of odds ratios.

**Results:** Mean dental age for the IG was lower than that for the CG in general. Specifically, this was true for girls (\( P < .05 \)). Differences in the distribution of the subjects based on the rate of dental development and occurrence of positional anomalies also reached statistical significance (\( P < .05 \)). The IG showed a higher frequency of late developers and positional anomalies compared with controls (odds ratios 3.00 and 2.82, respectively; \( P < .05 \)).

**Conclusions:** The null hypothesis was rejected. We identified close association of female subjects in the IG with retarded dental development compared with the female orthodontic patients. Increased frequency of positional developmental anomalies was also remarkable in the IG. (Angle Orthod. 2015;85:638–644.)

**KEY WORDS:** Impaction; Dental age; Developmental anomalies; Interception; Genetic; Agenesis

**INTRODUCTION**

Impaction of permanent mandibular canine (PMC) is a rare developmental disturbance of eruption.\(^1\) It is important to dentistry and particularly significant in orthodontics. Despite numerous studies of mechanisms, the specific cause remains unknown,\(^2\) though abnormal displacement of the tooth bud in embryonic life is a commonly accepted explanation.\(^3\) Other possible factors are inadequate space, premature loss of the deciduous dentition, excessive crown length, hereditary factors, functional disturbances of the endocrine glands, tumors, cysts, and trauma.\(^4-8\)

Assessment of dental age is important in orthodontics. To our knowledge, no study has yet been reported on the assessment of dental age in subjects with impacted PMCs. As far as developmental anomalies are concerned, there have only been a few studies associated with impacted mandibular canines. Peck\(^9\)
and Vichi and Franchi\textsuperscript{10} noted an elevated occurrence of hypodontia in patients with eruption disturbances of mandibular canines. Association of missing or small teeth with the tendency for delayed dental development is well established.\textsuperscript{11,12} Furthermore, retained deciduous teeth and supernumerary teeth have been linked to transmigrated mandibular canines.\textsuperscript{13} Numerous researchers have identified such dental anomalies as microsymptoms of a single inheritable developmental disturbance due to a generalized developmental defect.\textsuperscript{14,15} In the light of the aforementioned reports, it may be worth studying the dental development and potentially clinically relevant associations of various developmental anomalies in subjects with impacted PMCs.

Our aim in the present study was to test the null hypothesis that there is no difference in the rate of dental development and the occurrence rate of selected developmental anomalies related to shape, number, structure, and position of teeth between subjects with impacted PMCs and those with normally erupted canines.

**MATERIALS AND METHODS**

After obtaining the approval of the institutional review board, a cross-sectional clinical and radiographic study was designed and undertaken at the Department of Orthodontics, Purvanchal Institute of Dental Sciences (PIDS), Gorakhpur, India. This research was conducted in full accordance with ethical principles, including those from the 2008 Declaration of Helsinki.

We adopted a multistage sampling technique to select the subjects with impacted PMCs from various schools in the district of Gorakhpur. The district was divided into six zones based on Gorakhpur Municipal Corporation. A list of all the middle and high schools was procured for each zone, and then two schools were randomly selected from each list. All the students who were at least 14 years old were evaluated in each of the selected schools. Initially, a total of 10,422 subjects (4,937 girls, 5,485 boys) were screened. Of these, 67 subjects who lacked any clinical sign of eruption of at least one PMC were asked to get written informed consent from at least one parent to participate in the study. All these subjects were referred to the Department of Orthodontics, PIDS, for subsequent evaluation. Of the 63 subjects who reported to the department and underwent detailed radiographic investigations (orthopantomograph: occlusal, intraoral, and periapical views), 59 were diagnosed with impacted PMCs.\textsuperscript{16} The mandibular canine was classified as impacted if it met the following criteria:

- It was determined to be prevented from erupting by a physical barrier or because of its orientation in a position other than vertical within the periodontal structures.\textsuperscript{16}
- It showed radiographic evidence of complete root formation.\textsuperscript{16}
- It remained in the jaw 2 years after the respective mean age of its eruption.\textsuperscript{17}

Taking into account the aforementioned factors, a cutoff age of 14 years was established for this study. Dental models were poured only for the 59 subjects diagnosed with PMC impaction. This step was bypassed for the remaining four patients who showed unilaterally missing mandibular canines with normally erupted contralateral canine and were not interested in seeking subsequent treatment, this step.

Exclusion criteria were chronologic age >16 years (owing to decreased accuracy of dental age estimation using Acharya's method\textsuperscript{18}); bilateral agenesis of the mandibular teeth (other than PMCs), teeth that were missing because of previous extractions or traumas; presence of gross caries, previous endodontic treatment of primary mandibular canines that possibly influenced eruption of PMCs, orofacial clefts, or any syndromic manifestations and history of prior orthodontic treatment.

Finally, 42 subjects (30 girls and 12 boys) were considered for inclusion in the impaction group (IG). All the subjects were Indian by origin and had a chronologic age between 14 and 16 years (mean, 15.01 ± 0.57 years).

For the control group (CG), we refrained from using initially screened subjects as controls because of limited resources and because radiographic examination of the subjects who may not be aware of or considering orthodontic treatment would be unethical. It was considered justifiable to assemble a CG using pretreatment diagnostic records of patients undergoing orthodontic treatment at PIDS. Thus, the CG consisted of nonsyndromic Indian patients (60 girls and 24 boys) matched for chronologic age. All had complete eruption of both the PMCs, as evident from their pretreatment models. We excluded subjects with inadequate record quality or bilaterally missing mandibular teeth. These factors could have made it impossible to assess dental age by the method\textsuperscript{18} considered in this study.

To evaluate dental age, a single examiner who was blinded to the null hypothesis examined all the pretreatment orthopantomographs on a transparency projector under constant lighting conditions. Furthermore, a provision was made to hide the patient’s details on the respective radiographs from this examiner at the time of dental age assessment.
teeth on the mandibular left side from the mandibular central incisor to the mandibular third molar were scored based on Demirjian’s modified criteria, which included 10 stages of tooth development. If a tooth in the mandibular left quadrant was missing, the contralateral tooth was included in the study. Stages were entered into a separate scoring pro forma, after which the sex-specific maturity score for each tooth was entered depending on the scoring grade. These eight maturity scores were added to get a total maturity score (S), which was then substituted in Acharya’s India specific regression formula:

\[
\text{Age (Males)} = 27.4351 - (0.0097 \times S^2) \\
+ (0.000089 \times S^3)
\]

\[
\text{Age (Females)} = 23.7288 - (0.0088 \times S^2) \\
+ (0.000085 \times S^3)
\]

The value so obtained was designated as the dental age estimated. This method is further exemplified in Figure 1.

The chronologic age of the patients at the time the radiographs were taken was calculated by subtracting the patient’s birth dates, as recorded in their record files, from the dates recorded on the radiographs. The discrepancy between dental age and chronologic age was assessed for each subject. The subject was labeled as an early or late developer if there was a difference of ±2 years from the average value or a normal developer if the difference between their chronologic and dental age was within the range −2 to +2.

Dental anomalies were assessed independently of sex on account of statistically insignificant sex-based differences. They were identified from direct observation of the dental casts and confirmed by clinical observation, photographic examination (for controls and for selected subjects with impaction), and analysis of orthopantomographs. The following dental anomalies were analyzed:

- **Shape anomalies:** Only gross deviations easily discernible by clinical judgment were accepted. These included peg-shaped maxillary lateral incisor, its dimensions being measured using the established criteria; dens invaginatus; dens evaginatus; taurodontism; talon’s cusp; germination; and fusion.
- **Number anomalies:** Hypodontia/oligodontia (unilateral mandibular teeth agenesis, unilateral or bilateral

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**Table 1.** Distribution of Subjects with Permanent Mandibular Canine (PMC) Impaction

<table>
<thead>
<tr>
<th></th>
<th>Unilateral PMC Impaction</th>
<th>Bilateral PMC Impaction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>27</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Boys</td>
<td>10</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>37 (88.1%)</td>
<td>5 (11.9%)</td>
<td>42 (100%)</td>
</tr>
</tbody>
</table>

**Table 2.** Comparison of Mean Dental Age (years) Between the IG and CG

<table>
<thead>
<tr>
<th></th>
<th>IG (Mean ± SD)</th>
<th>CG (Mean ± SD)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>14.40 ± 1.75</td>
<td>15.07 ± 1.72</td>
<td>.042*</td>
</tr>
<tr>
<td>Girls</td>
<td>14.00 ± 1.79</td>
<td>14.95 ± 1.70</td>
<td>.017*</td>
</tr>
<tr>
<td>Boys</td>
<td>15.38 ± 1.23</td>
<td>15.37 ± 1.75</td>
<td>.982</td>
</tr>
</tbody>
</table>

* IG indicates impaction group; CG, control group.
* \(P < .05\), statistically significant independent two-sample \(t\)-test.
maxillary tooth agenesis (except third molars) and supernumerary teeth.

- Structural anomalies: Amelogenesis imperfecta, dentinogenesis imperfecta, odontodysplasia, dentin dysplasia, and dentin hypocalcification.

- Positional anomalies: Ectopic eruption defined as eruption of teeth in an abnormal position; impaction (other than third molars), as based on the criteria proposed by Becker; and rotation as considered subjectively for any evident (at least 20°) mesiolingual or distolingual intraalveolar displacement of tooth around its longitudinal axis.

Data consisting of gender; dental age; chronologic age; occurrence of late, normal, and early developers; and occurrence of various dental anomalies were collected and entered into a spreadsheet (Excel 2000, Microsoft Corporation, Redmond, Wash). Analyses were conducted using SPSS (version 17, Chicago, Ill).

### Statistical Analyses

The intraexaminer reliability for the diagnoses of PMC impaction and identification of dental age and associated anomalies was assessed by reexamining the diagnostic records of 30 (15 from each group) randomly selected subjects 3 weeks after the initial assessment. For measurement of random error in dental age assessment, the Dahlberg formula was used. Systematic error was evaluated with the paired t-test.

Mean dental age between the groups was compared using the independent two-sample t-test. The χ² test (Fisher exact test, when the expected counts in some of the table cells were <5) assessed the significance of distribution of subjects between the IG and CG based on their rate of dental development. It also assessed the intergroup differences in the distribution of various categories of selected dental anomalies. Odds ratio were used to evaluate the odds of late, normal, and early developers and various categories of developmental anomalies between the IG and CG. Results were assumed to be significant when the P value was <.05.

### RESULTS

Table 1 summarizes the distribution of subjects with PMC impaction, stratified by location and gender. Reproducibility was 100% for the diagnosis of PMC impaction and identification of dental anomalies. Random error in measurement of dental age was 0.06, and the systematic error was nonsignificant (P = .23).

In contrast to control subjects, dental development in general appeared to be retarded in subjects with impaction (Table 2). The independent two-sample t-tests showed that the difference in mean dental age between the two groups reached statistical significance for female subjects alone (P < .05). A statistically significant difference in the distribution of late, normal, or early developers was observed between the IG and CG (Figure 2; P = .006; χ² test). As shown in Table 3, the evaluation of the risk factors for IG/CG showed an odds ratio of 3.00 for late developers (P < .05).

Intergroup comparison of the frequencies of various categories of dental anomalies showed significant associations of positional disturbances with PMC.
impaction (Table 4; \( P = .008; \chi^2 \) test). Odds ratios used to evaluate selected developmental anomalies as prospective risk factors for impaction are shown in Table 5. The comparison of IG and CG demonstrated an odds ratio of 2.82 for positional anomalies \((P = .009)\). As a result, the null hypothesis was rejected.

**DISCUSSION**

We found the incidence of PMC impaction to be 0.4\% in an Indian subpopulation sample of 10,422 school-age subjects. The difference from earlier studies is likely attributable to racial factors, study design, and sampling variations.\(^2,25–27\) A predilection for female prevalence observed in the present study was strikingly more obvious compared with the findings of a previous report.\(^26\) Observations on the location of canine impaction (unilateral vs bilateral) however, closely paralleled that of a previous report.\(^27\)

As the developmental process is common to all teeth, it is unlikely that the development of different teeth is due to the action of different genes. A developmental problem in one tooth may reasonably be expected to affect all teeth to some degree.\(^1\) We planned to explore this issue by conducting a cross-sectional clinical and radiographic study to assess the rate of dental development and selected developmental dental anomalies in subjects with mandibular canine impaction. The results are likely to have diagnostic, prognostic, and therapeutic implications for a holistic approach to patient care.

As impacted mandibular canines are often discovered at the time of radiologic examination before any apparent symptoms that are suggestive of their presence, early recognition and interception of this particular dental anomaly should be of considerable value.\(^3\) The procedure of reducing the prevalence of impacted canines by extracting the corresponding deciduous canine has been reported in the dental literature since 1936.\(^28\) Such interceptive treatment decisions are often modified by the dental development/age of the patient.\(^29\) Table 2 shows that subjects with impaction in general, and girls specifically, show retarded dental development compared with the total number of subjects and girls with normally erupted canines, respectively. Statistical significance was reached for female subjects alone. Hence, it may be concluded that female subjects with impaction exhibit delayed dental development and/or maturation compared with other healthy female subjects who present to the orthodontist for unrelated problems. On the other hand, the rate of dental development in boys was found to be virtually similar. The present study also showed significant differences in the incidence of various classes of subjects based on the rate of their dental development. We observed an approximately twofold, statistically significant, more frequent occurrence of late developers in the IG (Figure 2). In fact, an odds ratio of 3.00 at the 95\% confidence interval indicated a significantly strong connection of PMC impaction and late developers (Table 3; \( P < .05 \)). Our results are in harmony with those of previous studies that identified a relationship between palatally displaced maxillary canines and late-developing dentition.\(^29,30\) From this perspective, we speculate that a small-sized or missing mandibular lateral incisor may be associated with delayed dental development and could possibly fail to navigate the erupting canine.\(^10–12,29–31\)

The search for associated dental anomalies is one of the most efficient investigative tools in the clinical study of the genetic determinants of eruption disturbances.\(^32,33\) Such anomalies may be mechanically (causally) or genetically (noncausally) related to the eruption disturbance studied.\(^33\) Of all the categories of developmental anomalies studied, evidence has been gathered here only to support a significant association of positional anomalies of teeth (other than third molars and PMCs) with PMC impaction. It is possible that positional anomalies like ectopic eruption and impaction demonstrated such an association primarily
because of orthodontic reasons, such as crowding. On the other hand, with respect to anomalies like tooth rotations, we contend that these could be expected in the subjects with PMC impaction as a consequence of genetic mechanisms in the etiology of intra-arch tooth malpositions. This is validated by the growing body of evidence identifying a complex of genetically controlled dental disturbances that often occur in combination.14-15 An odds ratio of 2.82 indicates that subjects with positional developmental disturbances of teeth are at an almost three times higher risk of presenting with PMC impaction (P < .05). The overall implication is that early diagnosis of PMC impaction could possibly be based on early identification of associated dental characteristics.

Owing to observational nature of the study and limitation in generalization of the results due to ethnicity-based differences, these findings must be considered preliminary; further verification in different populations with more elaborate resources and research tools is recommended. Furthermore, it should be of great interest, in view of the present findings, to investigate the probable etiology of labial vs lingual and unilateral vs bilateral PMC impaction in the context of various factors studied herein and determine if the genes associated with PMC eruption/impaction are also involved in determining dental age and associated dental anomalies.

CONCLUSIONS

- Compared with female orthodontic patients with normally erupted PMCs, those exhibiting PMC impaction revealed a trend toward delayed dental development. Risk of impaction was higher in subjects with delayed development of dentition.
- A significant association of other positional developmental anomalies with PMC impaction led to an approximately three times greater risk of impaction in their presence.

REFERENCES