

Article

Three-Month Radiographic Change in Premolar Cusp-Tip-to-Occlusal-Plane Distance Among Patients Who Underwent Extraction of Infraoccluded Primary Molars: A Retrospective Uncontrolled Case Series

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Abstract

Background: Infraocclusion of primary molars, frequently associated with ankylosis, may disrupt normal occlusal development and affect the permanent successor. **Aim:** To describe the short-term change in the two-dimensional radiographic distance between the permanent premolar cusp tip and the occlusal plane between a pre-extraction baseline (T0) and an approximately three-month follow-up (T1) in patients who underwent extraction of infraoccluded primary molars. **Design:** This small, retrospective, uncontrolled case series included 19 infraoccluded primary molars in 13 patients aged 9–14 years. Pre-extraction and approximately three-month follow-up panoramic radiographs were analyzed. The primary outcome was the change in premolar–occlusal plane distance between T0 and T1. **Results:** The mean distance was 11.43 ± 2.31 mm at T0 and 7.49 ± 1.84 mm at T1, with a mean paired reduction of 3.93 ± 1.74 mm (tooth-level sensitivity analysis, paired *t*-test, $p < 0.001$). At the patient level, all 13 patients showed a reduction in their mean tooth-level distance (exact two-sided sign test, $p = 0.00024$; exact 95% CI for the proportion, 75.3–100%). **Conclusions:** This exploratory case series documents a short-term temporal reduction in the measured two-dimensional distance in a cohort of patients who underwent extraction. Because of the uncontrolled design, small clustered sample, short follow-up, and potential measurement-related sources of error, the finding does not establish that extraction caused the change or predict complete premolar eruption.

Keywords: infraocclusion; ankylosis; primary molars; premolar eruption; early extraction; panoramic radiography



Received: 26 August 2026

Revised: 20 September 2026

Accepted: 19 October 2026

Published: 20 October 2026

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1. Introduction

Infraocclusion is defined as a tooth positioned below the occlusal plane in the absence of mechanical obstruction at a developmental stage when eruption should be complete. It most frequently affects primary molars and is strongly associated with ankylosis, characterized by fusion between cementum and alveolar bone with loss of periodontal ligament continuity [1–3].

When infraocclusion is associated with ankylosis, the affected primary molar may fail to follow the vertical development of the alveolar process, leading to progressive relative submergence compared with adjacent teeth.

Untreated infraocclusion may lead to tipping of neighboring teeth, space loss, lateral open bite, midline deviation, overeruption of antagonists, and altered eruption trajectory of the permanent successor [4–6].

The persistent alteration of the eruptive pathway of premolars, secondary to primary molar infraocclusion, not only delays their emergence into the dental arch but also increases the risk of structural and root development anomalies, such as dental dilacerations, which ultimately require complex multidisciplinary therapeutic approaches.

The prevalence of infraoccluded primary molars ranges from 1.3% to 8.9%, with mandibular second primary molars most frequently affected [1,2]. When a permanent premolar successor is present, the primary therapeutic objective is to ensure its physiologic eruption. Early extraction has been advocated in moderate to severe cases, particularly when exfoliation is delayed or occlusal disturbances are evident [5,7,8].

Although previous studies have reported changes in permanent successors after management of ankylosed primary molars, quantitative short-term radiographic data remain limited. The primary outcome of this study was the change in the two-dimensional radiographic distance between the buccal cusp tip of the permanent premolar and the occlusal plane, measured at the pre-extraction baseline (T0) and at the approximately three-month follow-up (T1). The aim of this retrospective, uncontrolled case series was to describe the magnitude of this short-term within-sample radiographic change. The study was exploratory and was not designed to distinguish the effect of extraction from spontaneous eruption, growth, root development, or other time-dependent changes. We hypothesized that the measured two-dimensional distance would be lower at T1 than at T0; this within-sample hypothesis did not imply a causal effect of extraction.

2. Materials and Methods

2.1. Study Design and Sample

A small, retrospective, uncontrolled case series was conducted by reviewing pre-existing clinical and radiographic records of patients treated at the Department of Maxillo-facial Surgery and Odontostomatology, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, and at the Department of Biomedical, Surgical and Dental Sciences, San Paolo Hospital. The retrospective record review and data analysis were conducted after ethics approval and before manuscript preparation. Patients were treated between January 2024 and July 2025. Retrospective record screening and data extraction were performed between July and December 2025.

Data provenance was limited by the retrospective archived material available for the present analysis. The retrievable information included the patient age range, the clinical indication for extraction, the presence of a developing permanent premolar successor, the T0 and T1 panoramic radiographs, and the radiographic measurements used for the analysis. The sample comprised consecutive cases meeting the predefined eligibility criteria and having the required pre-extraction and follow-up documentation. Sex distribution, detailed tooth distribution by arch, side, and tooth type, radiographic device and exposure parameters, detailed head-positioning records, and software details are reported in the Statistical Analysis and Radiographic Measurements sections. These unavailable variables were not retrospectively inferred or imputed. The retained analytical dataset preserved the patient identifier associated with each tooth-level paired measurement, allowing the 19 paired tooth observations to be grouped within the 13 patients for the patient-level analysis. Patient-level age values, premolar developmental stage, postoperative complications,

severity categories, and exact follow-up intervals were not retrievable. The total screening denominator, case-specific exclusion counts, and the number of potentially eligible patients lacking T1 imaging could not be verified from the retained analytical archive; therefore, selection bias cannot be excluded.

Records of patients aged 9–14 years who presented with infraoccluded primary molars and underwent extraction were reviewed.

Inclusion criteria were:

- Presence of at least one infraoccluded primary molar with clinical indication for extraction
- Radiographic evidence of a developing permanent premolar successor
- Availability of a pre-extraction panoramic radiograph
- Availability of a follow-up radiograph scheduled at approximately three months after extraction

Exclusion criteria included agenesis of the corresponding premolar, absence of extraction indication and radiographic distortion compromising measurement reliability.

A total of 19 infraoccluded primary molars in 13 patients fulfilled the inclusion criteria.

The clinical indication for extraction was established on the basis of the severity of infraocclusion and its potential interference with normal occlusal development and eruption of the permanent successor. Extraction was indicated in cases showing moderate-to-severe infraocclusion and/or clinical or radiographic evidence of delayed exfoliation, an altered eruption pathway of the permanent premolar, tipping of adjacent teeth, or loss of arch space. The decision to extract was made as part of routine clinical care before inclusion of the records in the present retrospective study. A representative extraction procedure is illustrated in Figure 1.

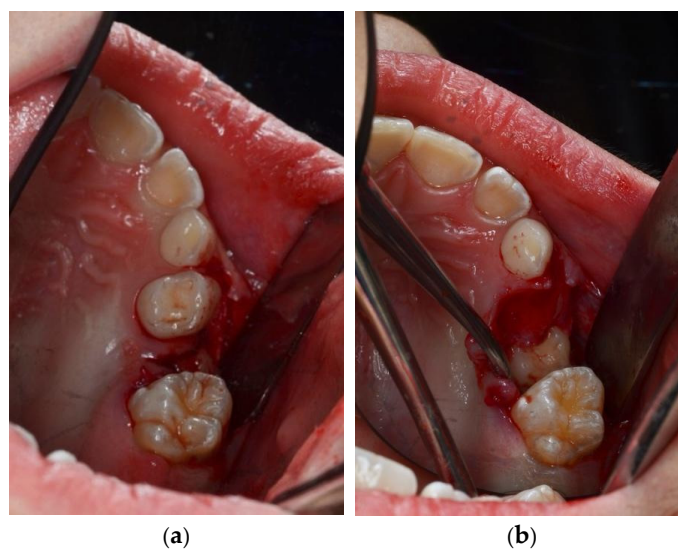


Figure 1. *Cont.*

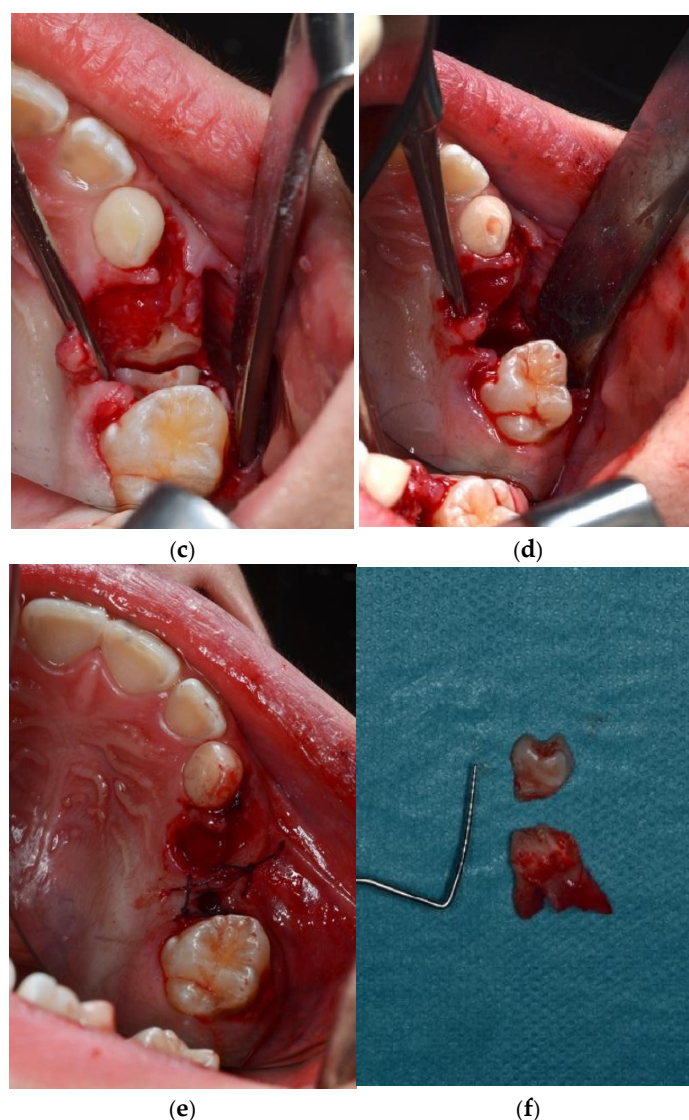


Figure 1. Extraction procedure for an infraoccluded upper primary molar: (a) access flap design; (b) full-thickness flap elevation; (c) odontotomy; (d) residual alveolus; (e) suture; (f) extracted tooth.

This retrospective, uncontrolled case series was based exclusively on clinical and radiographic records obtained during routine care. No additional imaging or clinical procedures were performed for research purposes.

The report was prepared with reference to the applicable items of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidance.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee of Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico (Operative Unit 420, Current Research No. 1; approval date: 10 January 2022). Approval preceded the retrospective review of the records included in this study. Written informed consent for the use of clinical and radiographic data was obtained from patients and their legal guardians. Consent also covered the use and publication of the intraoperative clinical photographs included in the manuscript.

2.2. Radiographic Measurements

Radiographic analysis was performed using ImageJ software (version 1.54u8; National Institutes of Health, Bethesda, MD, USA). Images obtained during routine clinical care. Before linear measurements, each image was individually calibrated using the clinically

recorded mesiodistal width of an adjacent tooth (the permanent first molar or second primary molar). The archived measurement documentation did not permit confirmation that the identical calibration tooth had been used at T0 and T1 in every case. The exact radiographic unit, exposure parameters, and detailed head-positioning records were not consistently retrievable. Therefore, calibration should be regarded as a pragmatic scale correction and not as complete correction for panoramic projection or positioning distortion. The recorded reference-tooth width had been obtained with a millimetric periodontal probe. Radiographs with distortion compromising measurement reliability were excluded; no separate formal image-comparability assessment was available.

The occlusal plane was defined as a line extending from the mesial marginal ridge of the permanent first molar to the cusp tip of the primary canine. This dentition-based reference has precedent in two-dimensional methods for quantifying primary-molar infraocclusion and was selected to represent the local occlusal orientation [9]. The occlusal table of the infraoccluded molar was defined by a line connecting its mesial and distal marginal ridges. Because this is a dental rather than a fixed skeletal reference, possible changes in the position of the reference teeth over time were considered in interpretation.

Infraocclusion severity was quantified as the perpendicular distance between the occlusal table of the infraoccluded molar and the occlusal plane.

The primary outcome was the change in the perpendicular distance between the buccal cusp tip of the permanent premolar and the occlusal plane, measured on the pre-extraction panoramic radiograph (T0) and on the follow-up radiograph scheduled at approximately three months (T1). Exact day-level T0-to-T1 intervals were not consistently retrievable from the archived documentation; therefore, interval length could not be analyzed as a covariate or correlated with the magnitude of change. The study did not assess complete eruption, eruption success, angulation, or three-dimensional trajectory. All intraoperative photographs included in the manuscript had also been obtained as part of routine clinical documentation and not according to a prospectively planned research protocol.

To assess intra-examiner reliability, measurements were repeated after a two-week interval on a random subset of radiographs. The archived documentation reported ICC > 0.90 for the repeated measurements. Formal blinding to timepoint was not feasible because the presence of the infraoccluded primary molar at T0 and its absence after extraction at T1 made the temporal status of the radiograph apparent to the examiner. Accordingly, the measurements should be regarded as unblinded with respect to timepoint. The requested subset size, ICC model, exact value with 95% confidence interval, and absolute-error estimate could not be verified. The procedure used to select the random subset, whether reliability was calculated separately for T0 and T1, whether the first or the mean of repeated measurements entered the final analysis, and whether Bland–Altman, standard-error-of-measurement, or limits-of-agreement data were likewise not retained.

2.3. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 32.0.0.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistics were calculated at tooth level. The 19 teeth were derived from 13 patients, and some patients contributed more than one tooth; therefore, tooth-level observations were clustered within patients and were not fully independent. The small number of patients did not support a stable multilevel or GEE model. Because the measured outcome was defined for each tooth and followed longitudinally from T0 to T1, the tooth remained the unit of measurement for descriptive reporting. To address within-patient dependence for inference, however, the exact two-sided sign test based on the direction of each patient's mean paired change was retained as the primary patient-level inferential

analysis. For patients contributing more than one tooth, the paired T0–T1 change was calculated for each tooth and then averaged within patient; the direction of change was defined by the sign of this patient-level mean paired difference. Tooth-level paired analyses and Cohen's *d* were retained as descriptive/sensitivity analyses.

Statistical significance was set at $p < 0.05$.

Normality of the paired differences was assessed using the Shapiro–Wilk test. Because the distribution of paired differences did not depart from normality, the paired *t*-test was reported as a tooth-level sensitivity analysis. Given the small sample, the Wilcoxon signed-rank test was additionally reported as a non-parametric robustness check rather than as a separate primary analysis.

In addition to hypothesis testing, effect size was calculated using Cohen's *d* for paired samples, defined as the mean paired difference divided by the standard deviation of the differences.

3. Results

Thirteen patients aged 9–14 years contributed 19 infraoccluded primary molars to the analysis. All teeth had a radiographically identifiable developing permanent premolar successor and fulfilled the predefined inclusion criteria. Additional demographic and detailed tooth-distribution variables were not available beyond the information described in the Data Provenance statement in the Methods. The mean depth of infraocclusion was 4.74 ± 2.10 mm (range: 2.43–10.09 mm).

At baseline (T0), the mean distance between the premolar cusp tip and the occlusal plane was 11.43 ± 2.31 mm (range: 9.30–18.46 mm). At the approximately three-month follow-up (T1), the mean premolar–occlusal plane distance was 7.49 ± 1.84 mm (range: 4.19–11.01 mm).

The mean paired reduction in premolar–occlusal plane distance was 3.93 ± 1.74 mm, with a tooth-level 95% confidence interval from 3.09 to 4.77 mm; this interval does not account for within-patient clustering.

The primary patient-level analysis showed a reduction for all 13 patients (13/13; exact two-sided sign test, $p = 0.00024$; exact 95% CI for the proportion, 75.3–100%). At tooth level, the paired *t*-test demonstrated a statistically significant within-sample difference between T0 and T1 values ($p < 0.001$). The Wilcoxon signed-rank test, used as a robustness check, yielded the same inferential conclusion ($p < 0.001$). Shapiro–Wilk testing indicated no evidence of non-normality of the paired differences.

A reduction in the measured premolar–occlusal plane distance was observed for all 19 analyzed teeth.

The standardized mean paired difference was Cohen's $d = 2.26$. This tooth-level descriptive estimate refers only to the magnitude of the observed within-sample change and should not be interpreted as an adjusted treatment effect or as evidence of clinical benefit.

The T0 maximum of 18.46 mm was treated as an extreme baseline observation. A leave-one-out sensitivity check excluding this observation did not alter the overall directional conclusion: all remaining 18 teeth still showed a reduction between T0 and T1. This leave-one-out check was treated as descriptive because the remaining tooth-level observations were still clustered within patients. Because the retrospective archive did not permit an independent adjudication of acquisition-related error for this single radiograph, the observation was not labeled as either erroneous or definitively biological (Figures 2 and 3, Table 1).

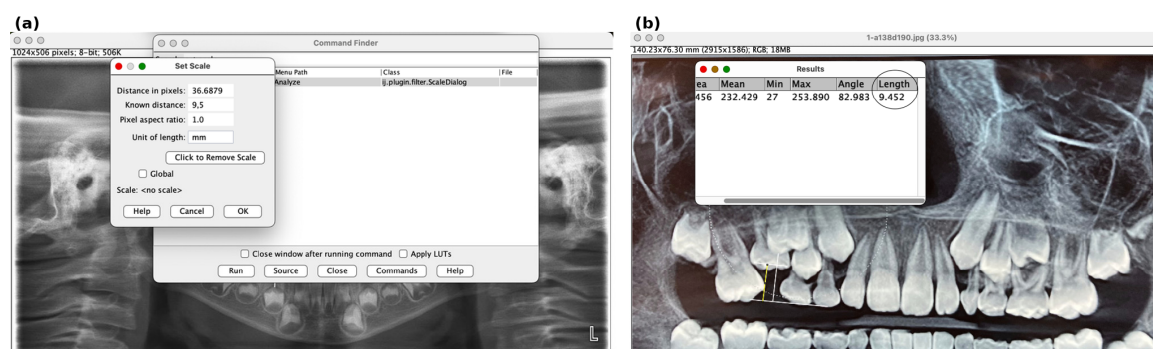


Figure 2. Representative radiographic methodology: (a) ImageJ calibration using the clinically recorded mesiodistal width of an adjacent tooth; (b) construction of the occlusal reference line and perpendicular cusp-tip-to-occlusal-plane distance.

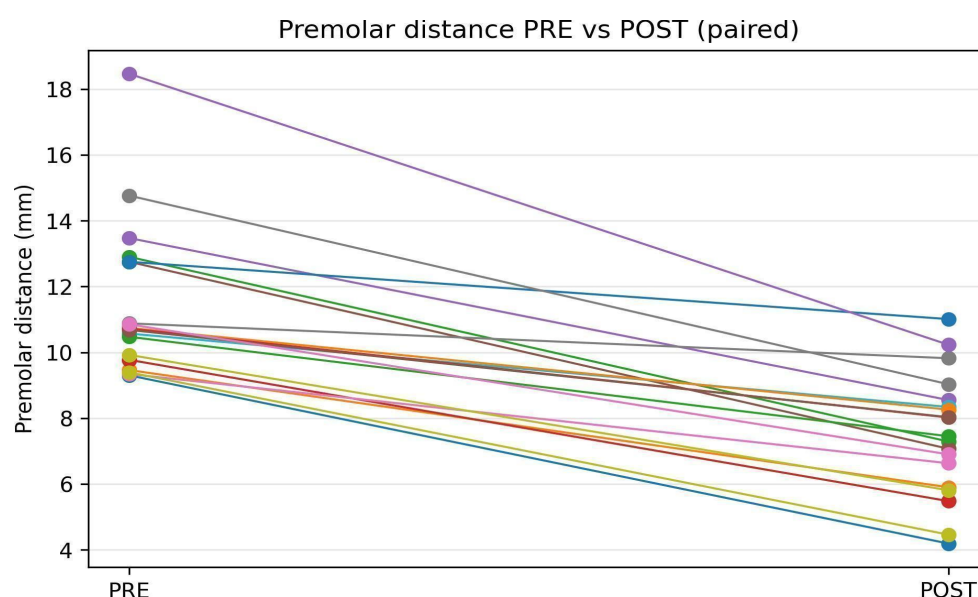


Figure 3. Paired plot of the premolar–occlusal plane distance at baseline (T0) and at the approximately three-month follow-up (T1), displaying all 19 tooth-level paired observations and the observed within-sample temporal change. The plotted pairs are descriptive tooth-level data; the primary inferential analysis was performed at patient level.

Table 1. Radiographic measurements of infraocclusion severity and premolar cusp-tip-to-occlusal-plane distance at T0 and T1.

Variable	Mean $\pm$ SD	Range
Infraocclusion depth (mm)	4.74 $\pm$ 2.10	2.43–10.09
Premolar–occlusal plane distance T0 (mm)	11.43 $\pm$ 2.31	9.30–18.46
Premolar–occlusal plane distance T1 (mm)	7.49 $\pm$ 1.84	4.19–11.01
Paired reduction (T0–T1) (mm)	3.93 $\pm$ 1.74	1.06–8.23

Primary patient-level analysis: exact two-sided sign test, 13/13 patients with reduction, $p = 0.00024$ (exact 95% CI for the proportion, 75.3–100%). Tooth-level sensitivity analyses: paired t -test $p < 0.001$; Wilcoxon signed-rank test $p < 0.001$.

4. Discussion

Infraocclusion of primary molars represents a clinically relevant condition in pediatric dentistry due to its potential to interfere with normal occlusal development and eruption of the permanent dentition. The pathogenesis is strongly associated with ankylosis, a condition characterized by fusion between cementum and alveolar bone resulting in loss

of the periodontal ligament space. Once ankylosis occurs, the affected tooth becomes unable to follow the vertical development of the alveolar process during growth, leading to progressive relative submergence compared with adjacent teeth [3,4].

The stability and health of the alveolar bone support around anchor teeth and primary molars represent a critical factor during transitional dentition stages and interceptive treatments [10]. Early extraction of the infraoccluded molar is intended to remove a potential local obstacle to eruption but also to prevent the loss of crestal bone support and the tipping of adjacent teeth.

The principal finding of the present study was a reduction in the two-dimensional radiographic distance between the permanent premolar cusp tip and the occlusal plane between T0 and the approximately three-month T1 assessment. The mean paired reduction was 3.93 ± 1.74 mm. This was the only outcome directly assessed and does not demonstrate complete eruption, eruption success, improved angulation, three-dimensional correction, or a causal effect of extraction.

These findings are consistent with previous studies investigating the eruption behavior of permanent successors associated with infraoccluded primary molars. Kurol reported that ankylosed primary molars diagnosed during mixed dentition may progressively increase in infraocclusion during active craniofacial growth, with vertical discrepancies increasing by approximately 1–2 mm over time if left untreated. Such progression may result in tipping of adjacent teeth, space loss, and development of lateral open bite, particularly in unilateral cases [11–13].

From a clinical perspective, this short-term radiographic change may be relevant to patient monitoring. However, the study did not assess final eruption, subsequent orthodontic treatment, or long-term occlusal outcomes; therefore, no conclusion regarding clinical benefit can be drawn from the present data.

The present study evaluated only the vertical cusp-tip-to-occlusal-plane distance on two-dimensional images. Whether the measured change was accompanied by correction of angulation, trajectory, or bucco-lingual position was not assessed.

The absence of an untreated comparison group prevents the observed temporal change from being distinguished from spontaneous eruption over the same period. Natural premolar eruption, craniofacial and alveolar growth, and the developmental and root-formation stage of each premolar may all have contributed to the reduction in distance; therefore, the measured change cannot be attributed specifically to extraction.

Previous longitudinal and observational studies have described the clinical course and management of infraoccluded or ankylosed primary molars [14–17]. These reports provide useful clinical context, but their findings cannot be used to separate the effect of extraction from normal developmental change in the present uncontrolled sample.

Other authors have reported radiographic changes in permanent successors following management of infraoccluded primary molars [18]. In the present study, however, only the vertical distance was measured; eruption angulation and trajectory were not evaluated.

The large standardized mean paired difference (Cohen's $d = 2.26$) describes the magnitude of the tooth-level within-sample change only. Statistical significance and effect size do not establish treatment efficacy or clinical relevance, particularly in a small uncontrolled sample in which 19 teeth were clustered within 13 patients. The primary patient-level sign test supports the consistency of the direction of change but does not solve the lack of a comparator or provide a cluster-adjusted estimate of effect magnitude.

Clinical management should remain individualized according to infraocclusion severity and progression, available space, the presence and developmental stage of the permanent successor, and potential effects on adjacent structures. The present findings do not

demonstrate that extraction reduces subsequent orthodontic treatment or is superior to alternative management strategies [19].

Early diagnosis remains important because progressive infraocclusion may be accompanied by tipping of adjacent teeth, space loss, or increasing difficulty of surgical removal [20]. Nevertheless, the present study did not compare early extraction with delayed intervention or observation.

This investigation used two-dimensional radiographs obtained during routine care, in accordance with radiation-minimization principles. Panoramic imaging is subject to magnification and projection distortion and cannot assess bucco-lingual position or three-dimensional eruption trajectory. In addition, the occlusal reference line was constructed from dental landmarks rather than stable skeletal landmarks. Eruption or positional change in the permanent first molar and/or primary canine during the follow-up interval could therefore alter the reference line itself and contribute to the measured T0–T1 difference independently of true premolar displacement.

Three-dimensional imaging could provide additional spatial information and has shown value in orthodontic and surgical diagnostic workflows [21,22]; however, additional CBCT exposure solely for research would not have been ethically justified in this pediatric sample. Calibration against an adjacent tooth may reduce scale differences but cannot eliminate errors related to projection and patient positioning. Because the same calibration tooth could not be verified for every T0–T1 pair and device-specific magnification data were unavailable, residual measurement error could not be quantified relative to the observed mean difference of 3.93 mm.

The available literature is heterogeneous and includes systematic and narrative reviews, longitudinal and observational studies, and case-based reports. Reviews emphasize individualized management according to infraocclusion severity, the presence of a permanent successor, and the risk of progressive occlusal disturbance [5,23–26]. Reports of severe infraocclusion have described failed or altered eruption of permanent successors [27–29] and developmental effects involving root resorption or the permanent successor [30].

Case-based and clinical reports illustrate the range of management problems encountered in selected patients, including space loss and space-regaining procedures [31–33], occlusal disturbances [34,35], restorative build-up [36,37], caries-related consequences [38], and complex presentations associated with hypodontia [39]. Population-based studies also show variability in prevalence and clinical features [6,40]. Some alterations of the oral cavity, such as macroglossia, may exert excessive and continuous mechanical forces on the dental arches, altering the neuromuscular balance of the oral cavity. This chronic pressure can interfere with normal dentoalveolar development, contributing to malocclusion, altered eruption patterns, and vertical occlusal disturbances. [41]. The approximately three-month follow-up in the present study does not permit evaluation of complete premolar eruption; accordingly, the measured reduction should be regarded as a short-term radiographic observation rather than evidence of eruption success or a prompt biological response to extraction [42,43].

The main limitations are the small retrospective sample, absence of a comparator group, short and not day-level-standardized follow-up, incomplete baseline demographic and tooth-distribution detail, inability to estimate a cluster-adjusted magnitude of change, unblinded timepoint assessment, inability to quantify residual panoramic projection error, use of a dentition-based reference line that may itself change over time, and reliance on a single two-dimensional measurement. Prospective controlled studies should use standardized imaging, stable and validated reference systems, record premolar developmental stage and exact follow-up intervals, account for multiple teeth within patients, and continue follow-up through clinical eruption.

5. Conclusions

This small, retrospective, uncontrolled case series describes a short-term temporal reduction in the two-dimensional radiographic distance between the permanent premolar cusp tip and the occlusal plane between a pre-extraction baseline and an approximately three-month follow-up in patients who underwent extraction of infraoccluded primary molars. The finding is exploratory and does not establish that extraction caused the observed change or predict complete eruption. Controlled studies with larger samples, patient-level statistical methods, standardized imaging and reference systems, and longer follow-up are required before clinical efficacy can be determined. The direction of change was consistent across all 13 patients in the patient-level sign test, whereas the magnitude of change remains descriptive at the tooth level.

Author Contributions: Conceptualization, C.M. and F.G.; methodology, L.G. and C.M.; validation, C.M., F.C.T. and S.S.; data curation, C.M.; writing—original draft preparation, S.S. and L.G.; writing—review and editing, L.G., F.G. and C.M.; supervision, C.M. and L.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study protocol was conducted in accordance with the Declaration of Helsinki and approved by the institutional ethics committee. This study was approved by the Research Protocol of Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Operative Unit 420, Current Research No. 1, 10 January 2022.

Informed Consent Statement: Written informed consent was obtained from all patients and their legal guardians for treatment and for the use of clinical and radiographic data for research and publication purposes. Consent also included the use and publication of the intraoperative clinical photographs presented in the manuscript.

Data Availability Statement: De-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical and privacy requirements. The data are not publicly available because they derive from pediatric clinical records.

Conflicts of Interest: The authors, Francesca Gaffuri, Lucia Giannini, and Cinzia Maspero, belong to the Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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