

Effect of dense bone islands on orthodontic tooth movement and root resorption during space closure with fixed orthodontic appliances: A longitudinal study on panoramic radiography

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Introduction: Idiopathic osteosclerosis (IO), also known as “dense bone island,” is a localized and well-defined radiopaque lesion often close to the radicular area of teeth. The present study investigated whether IO affected orthodontic tooth movement and root resorption during the closure of extraction spaces. **Methods:** A total of 1624 pretreatment and posttreatment panoramic radiographs were retrospectively screened. Forty adolescents and young adults who received orthodontic treatment with symmetrical mandibular premolar extraction and presented with unilateral IO were selected. Extraction space width, tooth length, and tooth angulation were measured pretreatment and posttreatment. The tooth was also identified as passing through or not passing through the lesion. Changes in tooth length and angulation between the IO side and non-IO side were compared using the Wilcoxon signed rank test. The prevalence of teeth passing through and not passing through was compared using the binomial exact test. **Results:** The size of the closed extraction space was similar on both sides ($P = 0.605$). Teeth on the IO side showed root resorption ($P = 0.706$) and angulation changes ($P = 0.568$) similar to those on the non-IO side. Among teeth having a clinically relevant movement, roots passed through the IO in 88% of the radiographs (95% confidence interval, 69.8%-97.6%, $P < 0.001$). **Conclusions:** In young patients undergoing fixed orthodontic treatment with premolar extractions, IO may not considerably affect changes in dental angulation, root resorption, and the extent of tooth movement during closure of extraction spaces. However, approximately 12% of teeth may encounter difficulties in passing through the lesion. (Am J Orthod Dentofacial Orthop 2026;169:75-86)

When additional space in the dental arch is required for orthodontic needs, the extraction of premolars is a commonly adopted strategy.¹ During closure of the extraction space, the

microvasculature of the periodontal ligament is constricted at the site of compression, leading to the recruitment of osteoclasts and osteoblasts that allow tooth movement via bone remodeling.² This process

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may be affected by an area of high bone density, such as a dense bone island, which is better defined as idiopathic osteosclerosis (IO)³:

*[A]symptomatic, non-expansive, osteosclerotic, radiopaque sometimes mixed (radiolucent–radiopaque) lesion, developing in the tooth-bearing area, that appears at any age, in both women and men, lacking any relationship with inflammatory, infectious or traumatic phenomena.*⁴

The diagnosis of IO is radiological, and panoramic radiography (PR) is the most appropriate initial examination, with a reported validity of 79.7%.⁵ It usually presents as a rounded, elongated, or irregular lesion <20 mm.⁶ Osteosclerotic lesions of similar radiographic appearance located in nontooth-bearing areas should not be considered IO, whereas analogous lesions in tooth-bearing areas related to an inflammatory process should be defined as condensing osteitis. Furthermore, differential diagnosis with other radiopaque masses, such as odontogenic and nonodontogenic tumors of the jaws, should be considered as well.⁴ For example, 3-dimensional (3D) imaging may be considered to rule out benign fibrous lesions presenting a surrounding radiolucent halo mimicking an IO overlapping the mandibular canal.⁷ Histologically, IO consists of dense cortical bone without bone marrow spaces or inflammatory infiltration.^{3,8} By definition (idiopathic = of unknown cause), the etiology of IO is controversial.⁹ It may be related to retained roots of primary molars that are resorbed and replaced by sclerotic bone, but data mainly suggest that IOs are developmental alterations or anatomic variants of the bone.^{4,10} The progression of the lesion can be variable, ranging from decreased size, complete disappearance, and maintenance until increase in size and number.⁷ Therefore, they should be considered labile lesions that retain a potential for enlargement or—to less extent—shrinkage with aging.⁶ The reported prevalence of IO ranges between 3% and 10%, with a higher prevalence in Asians.^{6,11,12} IO usually develops in early adolescence and has a higher incidence in young to middle-aged adults,¹³ who also have great requests for orthodontic treatment. Notably, the most frequent site of IO is the mandibular premolar and molar region,¹²⁻¹⁴ which is also the site in which greater orthodontic movement is needed for closing the extraction spaces. A case series suggested the potential risk of root resorption in the presence of IO,⁹ and a case report highlighted that an IO of large size may alter orthodontic treatment progress.¹⁵ Furthermore, it has been reported that other osteodense lesions may affect orthodontic tooth movement. For example,

condensing osteitis may be related to difficult orthodontic movement and root resorption,¹⁶ socket sclerosis can be an obstacle for orthodontic space closure,¹⁷ and florid cementoosseous dysplasia may be an absolute contraindication to orthodontic treatment.¹⁸ However, besides isolated case reports, the relationship between IO and orthodontic movement has not yet been clarified.

This study aimed to investigate the influence of IO on orthodontic tooth movement and root resorption in a group of young patients undergoing orthodontic treatment with a multibracket fixed vestibular appliance, all having symmetrical space closure after surgical extraction of mandibular premolars.

MATERIAL AND METHODS

All 1624 pairs of pretreatment and posttreatment PRs acquired for orthodontic purposes between 2000 and 2021 at the Prince Philip Dental Hospital and at the Institute for Advanced Dentistry (Faculty of Dentistry, The University of Hong Kong, Hong Kong SAR) were retrospectively collected and consecutively screened. Adolescents and young adults aged 10–28 years who received fixed orthodontic treatment, with symmetrical mandibular premolar extraction (either first or second premolars), with both pretreatment and posttreatment PR, and with mandibular IO unilaterally present in an area subject to orthodontic movement (so that the non-IO side could be used as a negative control) were selected. Patients with a history of orthognathic surgery, severe facial asymmetries or jaw deformities (eg, missing condyles or hemifacial microsomia), IO further than the apical level, or treated with devices other than a multibracket vestibular appliance (eg, clear aligners or removable appliances) were excluded. Ethical approval was obtained from the Institutional Review Board of the University of Hong Kong - West Cluster Hospital Authority (UW 18-187), which waived the need for informed consent because of the retrospective nature of the study. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013.

The sample size was calculated based on the difference between the IO side and the non-IO side in terms of posttreatment changes in dental angulation and root resorption. A pilot study was performed on 10 PRs of patients fulfilling the inclusion criteria, besides having an IO. The standard deviation (SD) of the posttreatment difference in dental angulation between the IO side and non-IO side in healthy patients was 6.6%, whereas it was 4.8% for root resorption. The calculation was based on a 2-tailed paired comparison by using the Wilcoxon

signed rank test, with power $\beta = 90\%$ and significance $\alpha = 5\%$. For dental angulation, the required sample size was 22 for detecting a clinically meaningful difference of 5.0° (a variation $<5.0^\circ$ may not alter treatment decisions when assessing tooth angulation on PR).^{19,20} For root resorption, the minimum sample size was 6 for detecting a clinically meaningful difference of 9.0% of tooth length (corresponding to a 2.0 mm shortening of a mandibular premolar, which represents the indication for pausing orthodontic treatment)²¹ (G*Power; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany).²² Given the retrospective nature of the study, the final sample size was 40.

Radiopacities on PRs were diagnosed as IO if they were not a mixed radiolucent and radiopaque area with the appearance of a fibroosseous lesion or periapical cemental dysplasia or odontoma, not surrounded by a radiolucent periphery, with no thickening of the lamina dura, not associated with identifiable tooth remnants, not associated with carious and/or restored and/or endodontically treated teeth, not associated with resorption of adjacent teeth before orthodontic treatment, found within a dentate portion of the alveolus, not a torus or exostosis or salivary calculus or tonsolith or calcified lymph node or stylohyoid ligament, and presenting no evidence of displacement of the inferior dental canal or floor of the antrum or adjacent tooth.⁴ The diagnosis of IO was performed by a specialist in orthodontics (F.S) and confirmed by a specialist in oral and maxillofacial radiology (R.T).

All measurements were taken with a computer software (ImageJ),²³ and the mesiodistal diameter of the mandibular first molar adjacent to the IO was used as a reference (unit) for scaling the linear measurements.²⁴ The occlusal line (on the IO side) was identified as the line joining the most occlusal point of each crown of the 2 teeth adjacent to the IO. The tooth whose root moved closer to the IO was selected for analysis, together with its respective contralateral, and numbered according to the dental numbering system for adult teeth of the World Dental Federation (Fédération Dentaire Internationale, FDI, ISO 3950 notation).²⁵ The center of the IO (IOctr) was identified by inscribing its contour into a circle, and the diameter of the circle was used to estimate the size of the IO. The center of the dental crown (CROctr) was identified as the midpoint of the maximum mesiodistal crown width. On the IO side, the crown position with respect to the IO (CROpos) was measured as the distance between the projection of IOctr and CROctr on the occlusal line. A positive value was assigned to the CROpos if the CROctr was mesial to the IOctr, and a negative value was assigned if the CROctr was distal to the IOctr. Then,

the dental movement was identified as mesialization or distalization. On both sides, the pretreatment and post-treatment tooth length was measured from the anatomic apex of the root to the most occlusal point of the crown (for molars, the root closer to the IO was measured).²⁶ The mesiodistal tooth angulation was measured as the angle between the long axis of the tooth (the line passing through the anatomic apex and most occlusal point of the crown; for molars, the line passing through the furcation and CROctr) and the maxillary line (the line along the hard palate and perpendicular to the midline bisector at the level of the nasal septum and anterior nasal spine).²⁷ The distance of the border of the IO from the dental roots was measured. The extraction space was measured as the distance between the contours of the crowns of the 2 teeth adjacent to the extraction site at pretreatment (Fig 1, A and B). By considering an average mesiodistal diameter of a mandibular first molar of 11.5 mm in the ethnicity of the target population,²⁸ the units were converted to mm (1 unit \approx 11.5 mm).

Statistical analysis

The normality of data distribution was checked using Shapiro-Wilk test. The pretreatment extraction space, posttreatment extraction space, and difference in space closure were compared between the IO side and non-IO side using Wilcoxon signed rank test. On the IO side, the crown movement with respect to the IO (CROmov, units) was measured as the absolute value of the difference in CROpos between posttreatment and pretreatment. Teeth were identified either as passing through the IO when the root moved within the lesion during treatment or not passing through in all the other instances (Fig 2). The application of this classification was limited to patients with complete space closure, CROmov ≥ 2 mm, and excluding patients with bilateral uncontrolled tipping $\geq 5^\circ$. Binomial exact test was used to compare the prevalence of teeth passing through and not passing through. Root resorption was estimated as the ratio between the difference in tooth length (between posttreatment and pretreatment) and the pretreatment tooth length (%). Then, root resorption was compared between the IO side and non-IO side using Wilcoxon signed rank test. The difference in root resorption between the IO side and non-IO side was calculated (%) and, considering negative values as representative of greater root resorption on the IO side, binomial exact test was used to compare the prevalence of root resorption between the 2 sides. Changes in dental angulation were calculated as the difference between posttreatment and pretreatment angulation ($^\circ$). Then, the change

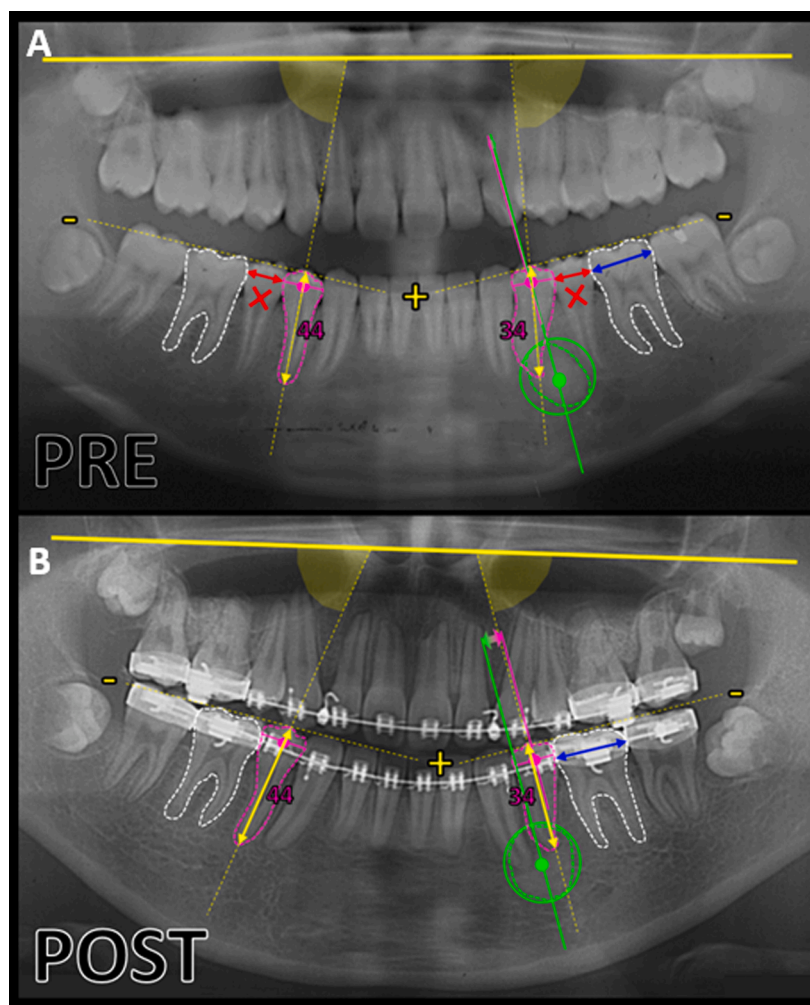


Fig 1. A, Pretreatment; **B,** Posttreatment. Occlusal dashed line (yellow); maxillary bulk line (yellow); IO contour dashed line (green); IO inscription circle (green); IO center dot (green) and its projection on the occlusal line (green); tooth contour dashed line (pink); crown center dot (pink) and its projection on the occlusal line (pink); adjacent tooth contour dashed line (white); reference unit arrow (blue); tooth length arrow (yellow); extraction space arrow (red); and tooth angulation (yellow).

in dental angulation was compared between the IO side and non-IO side using Wilcoxon signed rank test. The difference in the change of dental angulation between the IO side and non-IO side was calculated ($^{\circ}$) and, considering a greater change in dental angulation in the direction of tooth movement as representative of uncontrolled tipping (ie, distal tipping during distalization or mesial tipping during mesialization), binomial exact test was used to compare the prevalence of uncontrolled tipping between the 2 sides. The IO size and distance of the IO from the dental roots were compared between pretreatment and posttreatment using Mann-Whitney U test. The average measurement

between the primary and the secondary assessor was used for the final analysis, which was performed by using statistical software (SPSS [IBM, Armonk, NY] and StataCorp [StataCorp, College Station, Tex]) at a significance level $\alpha = 0.05$.

Records were measured by a primary assessor (F.S) and secondary assessor (K.D.T), both dentists and specialists in orthodontics, with training in PR analysis. Assessors were calibrated on the PR of 10 patients who were excluded from the study. The primary assessor repeated the measurements after a wash-out period of approximately 1 month. The intraclass correlation coefficient for single measurements (absolute agreement)

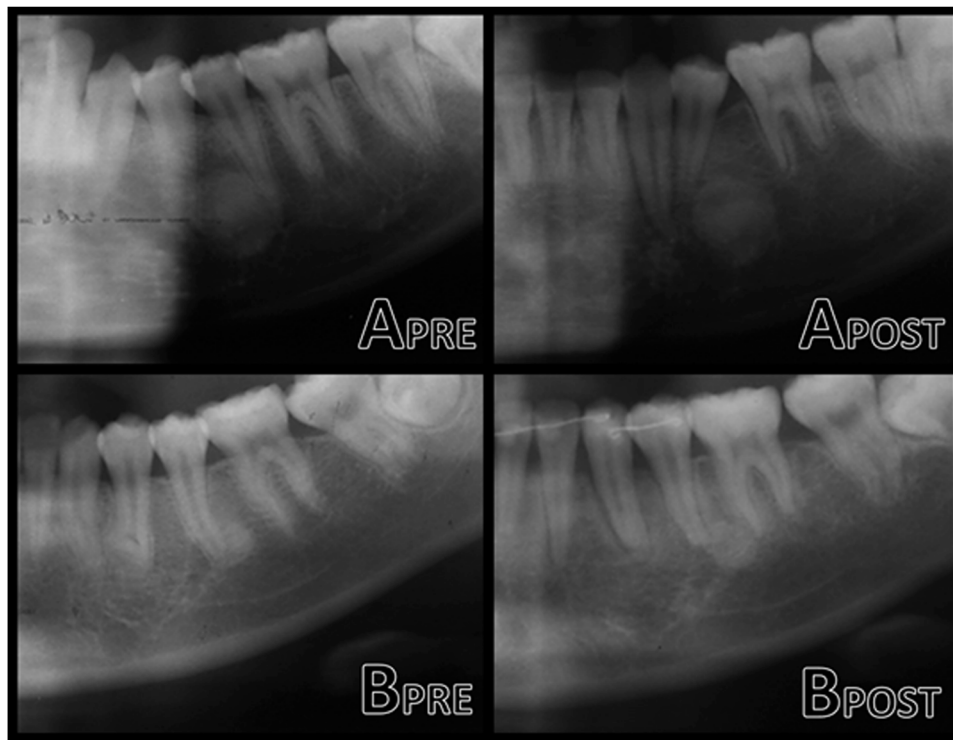


Fig 2. Movement through the IO, defined as not passing through the IO (A_{PRE} and A_{POST}) or passing through the IO (B_{PRE} and B_{POST}), after exclusion of patients with incomplete space closure, small crown movement, and evident uncontrolled tipping on both sides.

was used to measure the intraassessor and interassessor agreement of continuous variables (poor, <0.5 ; fair, $0.5-0.7$; good, $0.7-0.8$; excellent, >0.8 ; perfect, 1.0).²⁹ Cohen's κ coefficient was used to measure the intraassessor and interassessor agreement of categorical variables (low, <0.41 ; moderate, $0.41-0.60$; substantial, $0.61-0.80$; excellent, >0.80 ; perfect, 1.00).³⁰

RESULTS

The intraclass correlation coefficient was excellent (range, $0.893-0.997$) for all continuous variables, for both the intraassessor and the interassessor agreement. The agreement shown by kappa values about the assessment of whether the tooth was passing through the IO was substantial ($k = 0.750$), for both the intraassessor and interassessor agreement (the complete assessment is available in [Supplementary Tables I and II](#)).

A total of 1624 patients were screened, and 183 (11%) were identified with IO. Forty patients satisfied the inclusion criteria and were selected for further assessment. Of this sample, 14 were males (35%), and 26 were females (65%), with a mean age of 16.3 ± 4.0 years

(range, 11–28 years). Of the patients, 19 (48%) had extractions of the first mandibular premolars, whereas 21 (52%) had extractions of the second mandibular premolars. The average time between pretreatment and posttreatment PR was 3.4 ± 1.5 years, which corresponded to the average treatment duration. At pretreatment, the IO was located in the incisal region for 1 patient (3%), in the canine region for 7 patients (18%), in the premolar region for 16 patients (40%), and in the molar region for 16 patients (40%), showing no changes at posttreatment. At pretreatment, the average IO size was 0.8 ± 0.3 units (range, $0.4-1.4$ units), corresponding to 8.8 ± 3.1 mm (range, $5.0-15.5$ mm), and it did not show statistically significant changes at posttreatment ($P = 0.216$). At pretreatment, the distance of the IO from the dental roots was 0.0 ± 0.1 units (range, $0.0-0.5$ units), corresponding to 0.5 ± 1.0 mm (range, $0.0-5.9$ mm), showing a posttreatment reduction to 0.0 ± 0.1 units (range, -0.4 to 0.1 units), corresponding to approximately -0.2 ± 0.9 mm (range, -5.1 to 1.2 mm), which was not statistically significant ($P = 0.184$) (Table). Example PR images included in the final analysis are available in the [Supplementary Figures 1-5](#).

Table. Pretreatment and posttreatment characteristics of the IO, and changes in extraction space, tooth angulation, and root resorption

| Variables | Pretreatment | | | Posttreatment | | | Changes | | |
|--|--------------|-------------|--------------------|---------------|-------------|--------------------|--------------|--------------|---------------------|
| | IO side | Non-IO side | P value | IO side | Non-IO side | P value | IO side | Non-IO side | P value |
| IO size (unit) | 0.76 ± 0.27 | NP | NP | 0.75 ± 0.28 | NP | NP | -0.01 ± 0.11 | NP | NP |
| IO size (mm) | 8.78 ± 3.13 | NP | NP | 8.61 ± 3.27 | NP | NP | -0.17 ± 1.23 | NP | NP |
| IO distance from dental roots (unit) | 0.04 ± 0.09 | NP | NP | -0.02 ± 0.08 | NP | NP | -0.06 ± 0.13 | NP | NP |
| IO distance from dental roots (mm) | 0.49 ± 1.03 | NP | NP | -0.25 ± 0.94 | NP | NP | -0.74 ± 1.45 | NP | NP |
| Extraction space (unit) | 0.45 ± 0.11 | 0.45 ± 0.11 | 0.767 [†] | 0.01 ± 0.06 | 0.01 ± 0.04 | 0.465 [†] | -0.44 ± 0.12 | -0.44 ± 0.12 | 0.605 [†] |
| Extraction space (mm) | 5.16 ± 1.26 | 5.23 ± 1.31 | | 0.15 ± 0.70 | 0.12 ± 0.47 | | -5.00 ± 1.42 | -5.11 ± 0.36 | |
| Root resorption (%) | NA | NA | NA | NA | NA | NA | -2.6 ± 10.7 | -3.6 ± 10.0 | 0.706 [‡] |
| Change in tooth angulation (°) | NA | NA | NA | NA | NA | NA | -0.4 ± 9.8 | -0.1 ± 9.3 | 0.568 [‡] |
| IO position in the incisal region (%) | 3.0 | NP | NP | 3.0 | NP | NP | 0.0 | NP | NP |
| IO position in the canine region (%) | 18.0 | NP | NP | 18.0 | NP | NP | 0.0 | NP | NP |
| IO position in the premolar region (%) | 40.0 | NP | NP | 40.0 | NP | NP | 0.0 | NP | NP |
| IO position in the molar region (%) | 40.0 | NP | NP | 40.0 | NP | NP | 0.0 | NP | NP |
| Presence of root resorption (%) | NA | NA | NA | NA | NA | NA | 45.0 | 55.0 | 0.636 [‡] |
| Presence of uncontrolled tipping (%) | NA | NA | NA | NA | NA | NA | 55.0 | 45.0 | 0.636 [‡] |
| Tooth passing through the IO (%) | NA | NA | NA | NA | NA | NA | 88.0 | NP | <0.001 [§] |

Unit, mesiodistal diameter of the mandibular first molar on the IO side; *NP*, not possible because the IO was present unilaterally; *NA*, not available because it requires comparison between pretreatment and posttreatment.

[†]Wilcoxon signed rank test comparing the IO side with the contralateral side; [‡]Binomial exact test comparing the IO side with the contralateral side; [§]Binomial exact test comparing the prevalence of teeth passing through and not passing through the IO.

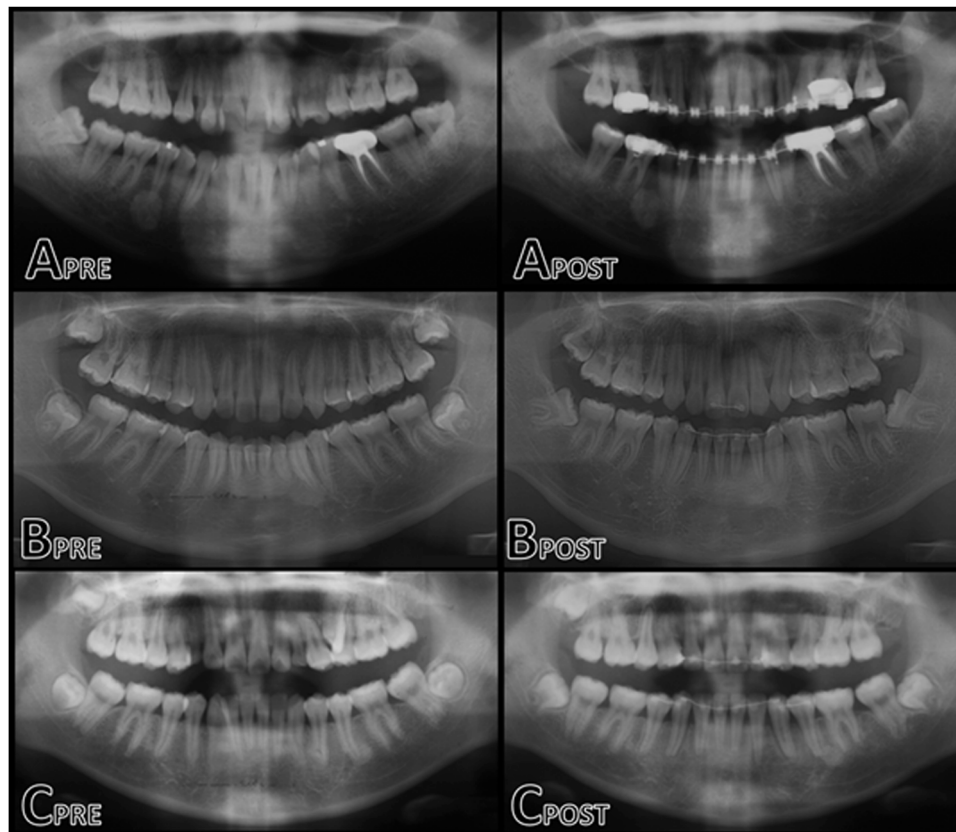


Fig 3. **A**, Example of a patient with the premolar appearing as not passing through the IO but showing a similar uncontrolled distal tipping during space closure on the non-IO side (thus, attributable to inefficient orthodontic mechanics), illustrating the importance of using the non-IO side as a control for correct identification of possible associations between altered tooth movement and the presence of IO. **B**, Example of a patient with the canine not passing through the lesion, with uncontrolled distal tipping on the IO side and control of canine angulation at the non-IO side, showcasing the possibility of IO affecting orthodontic tooth movement. **C**, Example of a patient with the tooth passing through the lesion with space closure via bodily movement on both sides, representing most of the patients included in this study.

Before treatment, the average extraction space was 0.45 ± 0.11 units (5.2 ± 1.2 mm) on the IO side and 0.45 ± 0.11 units (5.2 ± 1.3 mm) on the non-IO side, showing no statistically significant differences ($P = 0.767$). After treatment, the average extraction space was reduced to 0.0 ± 0.1 units (0.2 ± 0.7 mm) on the IO side and to 0.0 ± 0.0 units (0.1 ± 0.5 mm) on the non-IO side, showing no statistically significant differences ($P = 0.465$). Thus, the space closure on the IO side and non-IO side was similar, with no statistically significant differences ($P = 0.605$). After treatment, all extraction spaces were fully closed in 36 patients (90%), whereas 4 patients had an average residual extraction space of 0.2 ± 0.1 units (1.8 ± 1.4 mm) (Table).

Of the patients, 4 presented with incomplete space closure (2 bilaterally and 2 unilaterally), 6 patients showed a dental crown movement <2.0 mm on the IO side during space closure, and 4 had bilateral uncontrolled tipping (Fig 3, A). Among the remaining 26 patients, the teeth did not pass through the IO in 3 patients (12%) ($P < 0.001$) (Fig 3, B) and passed through the IO in 23 patients (88%) (Fig 3, C). The success rate of tooth passing through the IO ranged 69.8%-97.6% (95% confidence interval). The average rate of root resorption after treatment was $-3\% \pm 11\%$ on the IO side and $-4\% \pm 10\%$ on the non-IO side ($P = 0.706$). After treatment, 18 patients (45%) showed greater root resorption on the IO side, whereas the other 22 (55%) showed greater root resorption on the non-IO

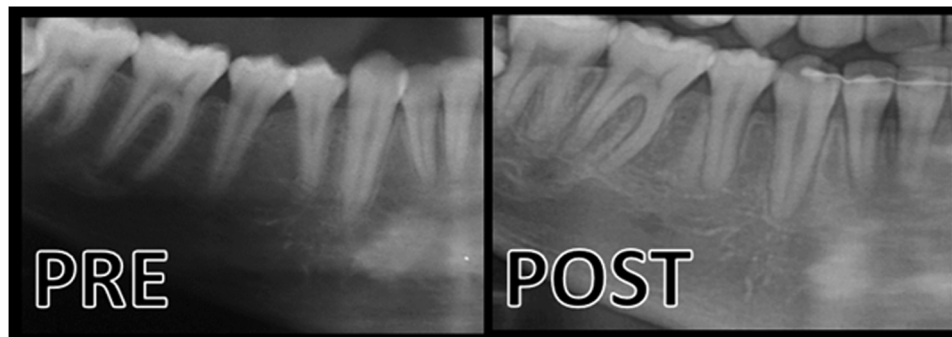


Fig 4. Example of a patient with the IO located in the anterior region of the mandible and orthodontic movement limited to mesialization of the posterior teeth. The patient was excluded because it was not relevant for the purpose of this study (A_{PRE} and A_{POST}).

side ($P = 0.636$). The average change in angulation after treatment was $-0.4^\circ \pm 9.8^\circ$ on the IO side and $-0.1^\circ \pm 9.3^\circ$ on the non-IO side ($P = 0.586$). After treatment, 22 patients (55%) showed uncontrolled tipping on the IO side, whereas the remaining 18 patients (45%) showed uncontrolled tipping on the non-IO side ($P = 0.636$) (Table).

DISCUSSION

This study selected a cohort of patients with unilateral presence of IO and undergoing orthodontic treatment, and used PRs to investigate the association between the presence of IO and changes in tooth movement and root length comparatively with the non-IO side. However, providing a meaningful estimate of such effects is complicated by several factors: (1) the low prevalence of IOs in the population (requiring occasional findings on PR), (2) the impossibility of using absolute measurements with respective calibration scales (because of the nonuniform image distortion on PR), (3) the biological variations and treatment diversity among patients (needing an internal control), (4) the need of having the lesion in a clinically meaningful position with respect to orthodontic tooth movement (the IO must be on the path of the root movement), and (5) the requisite of a sufficient amount of crown movement on the IO side (to allow meaningful judgment of the ability of the tooth to pass through the lesion). Overall, the analyzed cohort presented IO with relatively similar characteristics, given that 80% of the lesions were located in the premolar and molar regions, had a comparable size that ranged between approximately 5.0 and 15 mm, and were located within approximately 6.0 mm from the dental roots. After treatment, the distance of the IO from the dental roots changed from 0.5 mm to negative 0.2 mm, indicating that the roots either

contacted or passed through the lesion. Previous studies have reported a prevalence of IO of approximately 6% among the Hong Kong population in the 1980s and 1990s,¹² whereas this study showed a prevalence of approximately 11%. However, these data may not represent the true prevalence of IO, which would require random sampling from the general population, and selection bias may affect the estimation between studies.

Overall, no statistically significant differences in the relative amount of root resorption were present between the IO side and non-IO side. The difference between the 2 sides was close to 1%, which was also clinically irrelevant.²¹ In addition, the proportion of patients with greater root resorption on the IO side was similar to that on the non-IO side (45% vs 55%, respectively), a difference that was not statistically significant. Notably, estimating the severity of root resorption in terms of absolute values (mm) was beyond the scope of the present study, which aimed at comparing the IO side with the non-IO side. A previous study showed that density and morphology of the alveolar bone may not be etiologic factors for external apical root resorption.³¹ However, another study showed a patient with evident root shortening after orthodontic treatment, unilaterally on the IO side.⁹ As a consequence, the risk of root resorption during tooth movement in proximity to IO should not be completely excluded.

To perform a meaningful assessment, all patients included in this study had an extraction of mandibular premolars, and all IOs were located in the mandible coronally to the apex of the teeth and in an area subject to orthodontic movement. In addition, the position of the IO was coherent with the direction of such movement (ie, mesial to teeth moving mesially, and distal to teeth moving distally), to be clinically relevant regarding possible interferences (Fig 4). Ideally, the extraction

space should be closed by bodily movement, and tipping was considered “uncontrolled” when it was directed toward the direction of the dental translation (ie, distal tipping during distalization or mesial tipping during mesialization). Modern orthodontic fixed appliances allow for symmetrical control of dental angulation,³² and uncontrolled tipping unilaterally present on the IO side should be attributed to the interference caused by the lesion. However, no difference was present in the closure of the extraction space or the changes in dental angulation between the IO side and non-IO side, suggesting that IO may not influence orthodontic tooth movement during space closure. In particular, the difference in the change in dental angulation between the 2 sides was smaller than 1°, which was not clinically relevant,^{19,20} and the proportion of patients with uncontrolled tipping on the IO side was similar to that on the non-IO side (55% vs 45%, respectively). The principal mechanisms of bone matrix failure are strongly dependent on local strain type, and differential strain between the dense IO and surrounding trabecular bone may generate microcracks.³³ Such microdamages are potent factors enhancing orthodontic bone remodeling, which may lead the IO side to show tooth movement similar to that on the unaffected side.³⁴ Nevertheless, a previous case report showed limitations in orthodontic tooth movement because of the presence of an IO with unusual presentation.¹⁵ Notably, the lesion was uncommonly large (24 mm) and located in the maxilla, which may occur in <4% of patients.³⁵ Additional studies showing limitations in dental movement reported intrabony radiopaque lesions other than IO,¹⁶⁻¹⁸ and this work may be the first to perform a statistical assessment of possible effects of IO on orthodontic tooth movement. For a clinically meaningful assessment, the amount of dental movement should also be considered. However, the lack of a fixed reference undermined the possibility of measuring the crown movement on the non-IO side, which could have been used as a proxy for the expected movement on the IO side. Nevertheless, the IO can be used as a fixed reference and allowed the measurement of the crown movement on the IO side. Still, the crown movement may be small and may not allow proper judgment of the ability of the respective root to pass through the lesion. Finally, complete space closure with relevant crown movement may also happen because of bilateral uncontrolled tipping, which should be attributed to poor orthodontic mechanics and not to the presence of IO (Fig 3, A). Therefore, patients with crown movement <2 mm on the IO side or exhibiting bilateral uncontrolled tipping were excluded, with most of the remaining patients (88%) showing the tooth passing through the lesion. In terms of statistical chance of

“passing through” the IO, the expected success rate was between 69.8% and 97.6% based on a 95% confidence interval. These data suggest that the presence of an IO may not justify major changes to the optimal orthodontic treatment planning. However, isolated patients with IO preventing the tooth from moving through the lesion are possible (Fig 3, B), and clinicians should inform patients about the potential effects on their treatment. Radiological follow-up of the lesion may be performed to evaluate possible increases in the size of the IO that may require differential diagnosis with other bone pathologies,³⁶ or to intercept interference with ongoing orthodontic tooth movement.

PR is the most appropriate examination for the initial diagnosis of IO,⁷ with a reported validity of 79.7% compared with cone-beam computed tomography (CBCT).⁵ However, PR does not allow for assessment of the buccolingual position and extension of the lesion. Previous reports and current findings comparing PR with CBCT (Fig 5, A–C) showed that IO often occupies most of the buccolingual width of the alveolar bone.^{7,13,36} Hence, given that the average size of IO was approximately 9 mm, it is reasonable to assume that the tooth would contact the lesion during space closure. In addition, image distortion on PR is variable,³⁷ compromising the use of absolute values for accurate measurement of distances and angles. Furthermore, orthodontic treatment may change the dental inclination and alter the perceived tooth length on PR.^{38,39} Nevertheless, image distortion is symmetrical with respect to the facial midline, and this study performed a relative comparison of dental movement and root resorption between the left and right sides. Such design reduced the bias because of possible differences in orthodontic mechanics and biological characteristics among patients and also accounted for changes in root length in those patients with ongoing root development. Notably, a previous study comparing PR with CBCT and another study comparing PR with physical measurements showed symmetrical image distortion with respect to the midline.^{40,41} Furthermore, CBCT provides accurate measurement of distances and angles and allows the precise estimation of the spatial relationship between dental roots and the IO.⁴² However, it is not recommended to acquire further 3D imaging for the diagnosis of IO except in specific patients such as lesions affecting the mandibular canal,⁷ in accordance with the principle of *as low as diagnostically acceptable being indication oriented and patient-specific*.⁴³

The exclusion criteria of the IO to be symptomatic or to be present in patients with bone metabolic disorders were not considered because of the retrospective nature of the study.⁴ These findings were limited to the use of

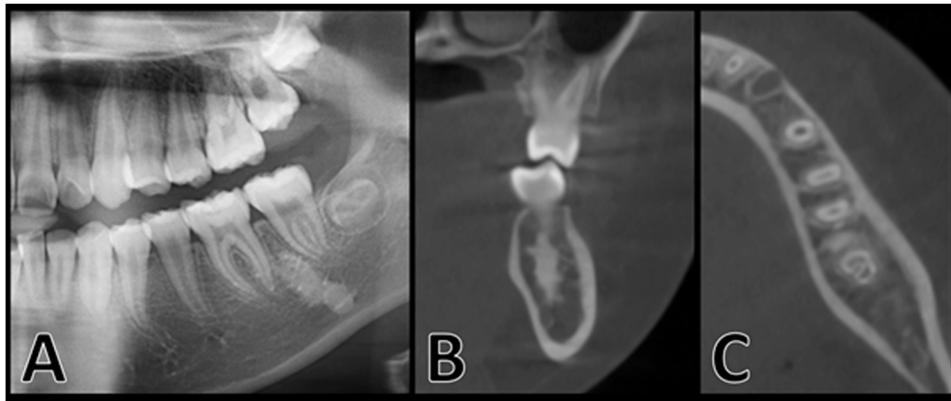


Fig 5. Example of a patient showing IO located at the interradicular area between 36 and 37. Notably, the IO extends from the buccal surface of the mandible to the lingual cortical bone. The reconstructed panoramic image (A) and the coronal (B) and axial (C) CBCT images are shown.

fixed multibracket vestibular appliances and might not apply to removable appliances or clear aligners. Symmetry was assumed between the left and right side of the dental arch in terms of orthodontic mechanics, despite such an assumption not being confirmed from the clinical records. Thus, it cannot be excluded that the orthodontist was aware of the presence of an IO in a relevant area, thereby including biomechanical adjustments that might have affected the actual passing through rate. Prospective studies are needed to ensure symmetrical orthodontic mechanics and force magnitude between the IO side and non-IO side (or to control for these factors by measuring biomechanical parameters during treatment) and to provide accurate quantification of dental root resorption and precise assessment of the anatomic relationship between the root and IO (by using 3D imaging methods such as CBCT). Finally, by measuring dental movement at the crown level, isolated cases of relevant root movement associated with limited crown movement might have been excluded from the calculation of the prevalence of teeth passing through the IO. Despite these limitations, and previously discussed implications of using PR imaging, this work seems to be the best currently available evidence about the effect of IO on orthodontic tooth movement.

CONCLUSIONS

In adolescents and young adults undergoing orthodontic treatment with fixed vestibular appliances and symmetrical extraction of mandibular premolars:

1. IO was not associated with an evident increase in root resorption compared with the unaffected contralateral side and may not represent a limita-

tion to tooth movement in most patients. Nevertheless, the lesion might undermine orthodontic movement in approximately 12% of patients.

2. Orthodontists should not alter the standard treatment protocols solely based on the presence of IO. However, effects related to lesions of large size that are located within the radicular area should not be entirely excluded, and radiological follow-up during orthodontic treatment is advisable.
3. These findings should be considered and generalized with caution, considering the variability of orthodontic biomechanics and the limitations of 2-dimensional imaging methods.

AUTHOR CREDIT STATEMENT

Fabio Savoldi contributed to conceptualization, data curation, formal analysis, methodology, validation, original draft preparation, and manuscript review and editing; Kieran Daniel Tsang contributed to data curation, formal analysis, investigation, methodology, validation, and manuscript review and editing; Lynton Edviano Loo contributed to investigation and original draft preparation; Yan Tsz Leung contributed to investigation; Yanqi Yang contributed to resources, supervision, and manuscript review and editing; Min Gu contributed to conceptualization, methodology, resources, supervision, and manuscript review and editing.

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SUPPLEMENTARY DATA

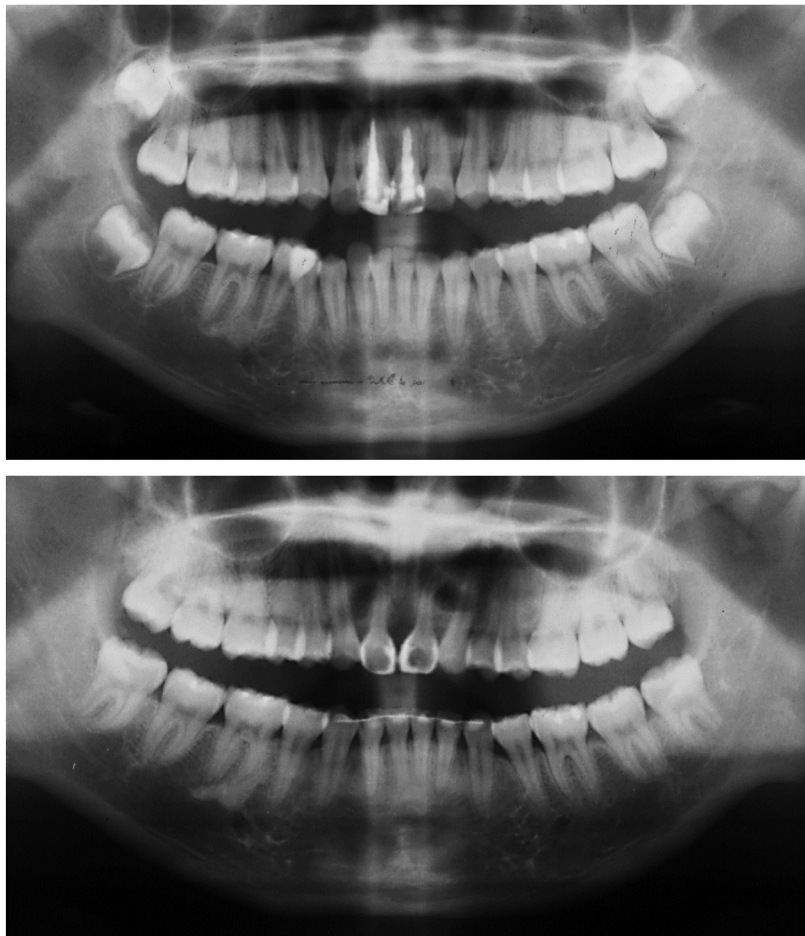
Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.ajodo.2025.09.008>.

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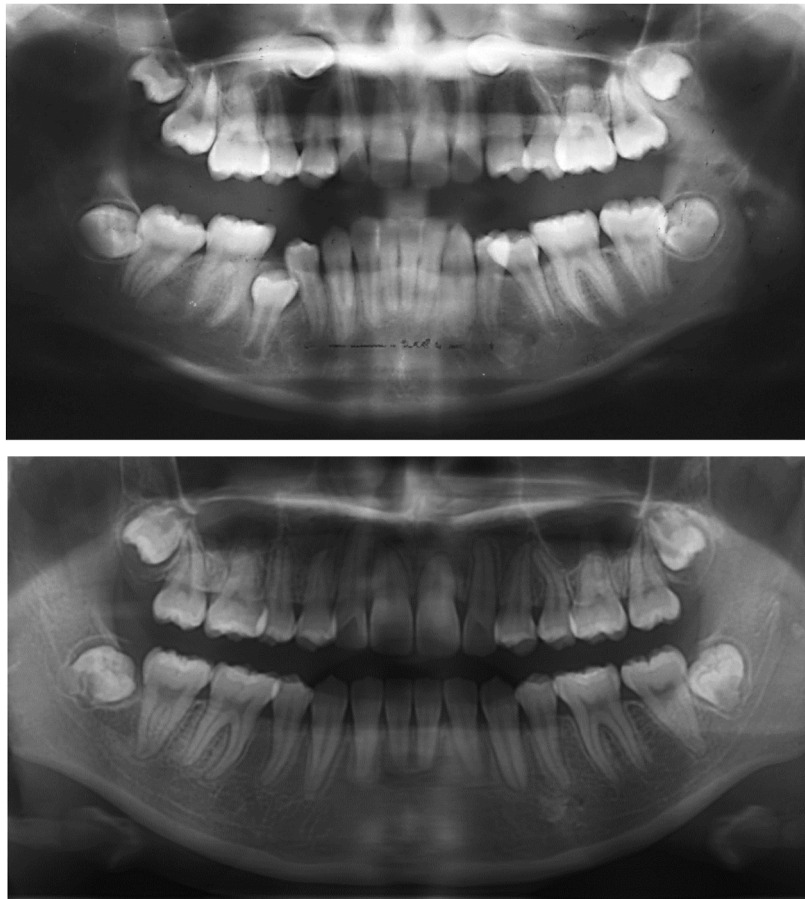
SUPPLEMENTARY DATA



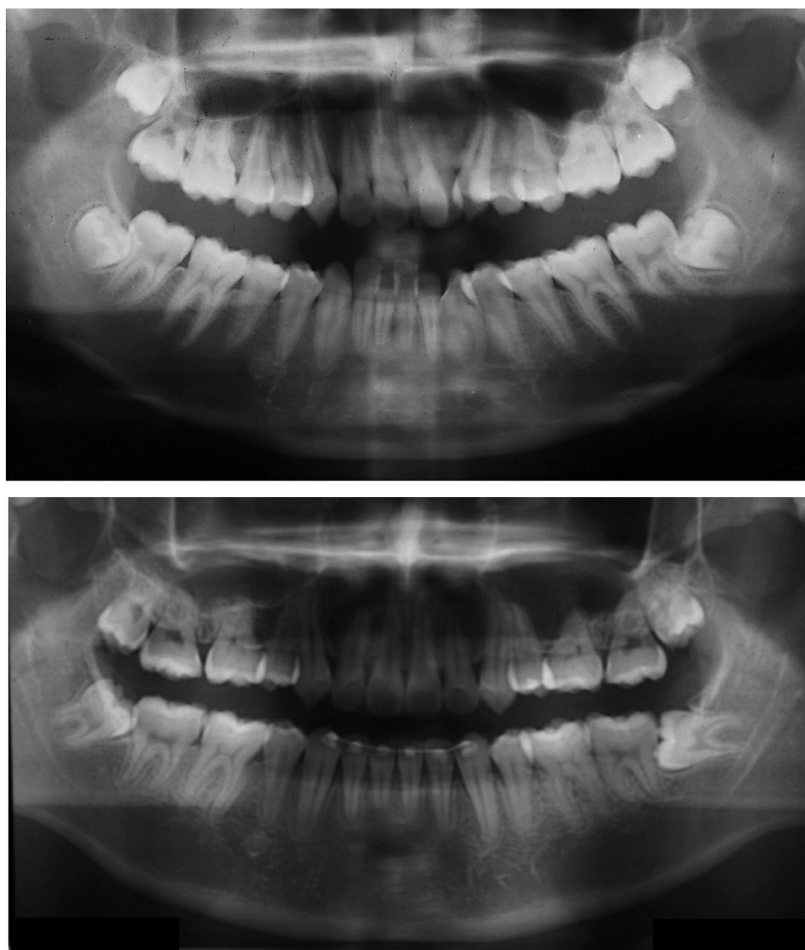
Supplementary Fig 1. Twelve-year-old, tooth number 46.



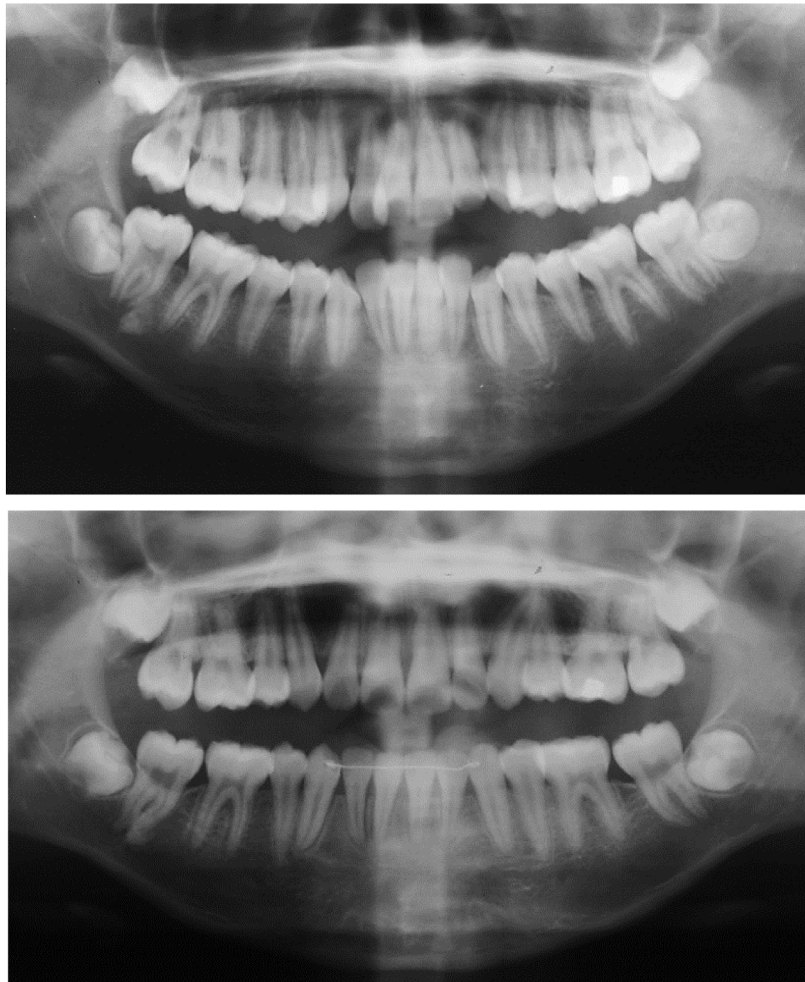
Supplementary Fig 2. Thirteen-year-old, tooth number 47.



Supplementary Fig 3. Thirteen-year-old, tooth number 34.



Supplementary Fig 4. Fifteen-year-old, tooth number 44.



Supplementary Fig 5. Thirteen-year-old, tooth number 47.

Supplementary Table I. Intraassessor agreement of the measurements performed on the dental panoramic radiographs, with the respective values of the ICC

| <i>Variables</i> | <i>Unit</i> | <i>ICC</i> | <i>k-coefficient</i> |
|--|-------------|------------|----------------------|
| Categorical variables | | | |
| Whether the tooth passed through the IO | yes/no | | 0.750 |
| Continuous variables (pretreatment) | | | |
| Mesiodistal diameter of the first molar on the IO side | pixel | 0.914 | |
| IO size | pixel | 0.978 | |
| IO distance from dental roots | pixel | 0.986 | |
| Extraction space on the IO side | pixel | 0.965 | |
| Extraction space on the non-IO side | pixel | 0.973 | |
| Crown position on the IO side | pixel | 0.961 | |
| Tooth length on the IO side | pixel | 0.939 | |
| Tooth length on the non-IO side | pixel | 0.893 | |
| Tooth angulation on the IO side | pixel | 0.955 | |
| Tooth angulation on the non-IO side | pixel | 0.980 | |
| Continuous variables (posttreatment) | | | |
| Mesiodistal diameter of the first molar on the IO side | pixel | 0.992 | |
| IO size | pixel | 0.981 | |
| IO distance from dental roots | pixel | 0.949 | |
| Extraction space on the IO side | pixel | 0.997 | |
| Extraction space on the non-IO side | pixel | 0.992 | |
| Crown position on the IO side | pixel | 0.978 | |
| Tooth length on the IO side | pixel | 0.985 | |
| Tooth length on the non-IO side | pixel | 0.989 | |
| Tooth angulation on the IO side | pixel | 0.906 | |
| Tooth angulation on the non-IO side | pixel | 0.992 | |

ICC, intraclass correlation coefficient for single measurements (absolute agreement).

Supplementary Table II. Interassessor agreement of the measurements performed on the dental panoramic radiographs, with the respective values of the ICC

| <i>Variable</i> | <i>Unit</i> | <i>ICC</i> | <i>k-coefficient</i> |
|--|-------------|------------|----------------------|
| Categorical variables | | | |
| Whether the tooth passed through the IO | yes/no | | 0.750 |
| Continuous variables (pretreatment) | | | |
| Mesiodistal diameter of the first molar on the IO side | pixel | 0.869 | |
| IO size | pixel | 0.889 | |
| IO distance from dental roots | pixel | 0.839 | |
| Extraction space on the IO side | pixel | 0.945 | |
| Extraction space on the non-IO side | pixel | 0.985 | |
| Crown position on the IO side | pixel | 0.944 | |
| Tooth length on the IO side | pixel | 0.979 | |
| Tooth length on the non-IO side | pixel | 0.977 | |
| Tooth angulation on the IO side | pixel | 0.875 | |
| Tooth angulation on the non-IO side | pixel | 0.941 | |
| Continuous variables (posttreatment) | | | |
| Mesiodistal diameter of the first molar on the IO side | pixel | 0.989 | |
| IO size | pixel | 0.959 | |
| IO distance from dental roots | pixel | 0.943 | |
| Extraction space on the IO side | pixel | 0.951 | |
| Extraction space on the non-IO side | pixel | 0.991 | |
| Crown position on the IO side | pixel | 0.930 | |
| Tooth length on the IO side | pixel | 0.987 | |
| Tooth length on the non-IO side | pixel | 0.989 | |
| Tooth angulation on the IO side | pixel | 0.803 | |
| Tooth angulation on the non-IO side | pixel | 0.904 | |