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Prevalence of infraocclusion of primary molars determined using a new 2D image analysis methodology

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Abstract

Background: The reported prevalence of infraocclusion varies widely, reflecting differences in definitions and measurement/scoring approaches.

Aims: This study aimed to quantify the prevalence and extent of infraocclusion in singletons and twins during the late mixed dentition stage of dental development using a new diagnostic imaging method and objective criteria. The study also aimed to determine any associations between infraocclusion and sex, arch type, arch side and tooth type.

Design: Two samples were analysed; 1,454 panoramic radiographs of singletons and 270 dental models of twins. Both samples ranged in age from 8-11 years. Adobe Photoshop CS5 was used to measure the extent of infraocclusion. Repeatability tests showed systematic and random errors were small.

Results: The prevalence in the maxilla was low (<1%), whereas the prevalence in the mandible was 22% in the singleton sample and 32% in the twin sample. The primary mandibular first molar was affected more often than the second molar. There was no significant difference in the expression between sexes or sides.

Conclusion: A new technique for measuring infraocclusion has been developed with high intra- and inter-operator reproducibility. This method should enhance early diagnosis of tooth developmental abnormalities and treatment planning during late mixed dentition stage of development..

Key words: Tooth eruption, submerged teeth, primary dentition

Introduction

The term 'infraocclusion' refers to a tooth that is positioned below the level of the occlusal plane. Infraocclusion can be associated with local and/or systemic abnormalities that may lead to disturbances or disorders within the erupting and functioning dentition. The aetiology, pattern of expression and degree of severity of infraocclusion are determined by the relative contributions of genetic, epigenetic and environmental factors.[1-3] Infraocclusion can be associated with other local factors such as loss of space, trauma to teeth, hypodontia, ectopic canines and the lateral incisor complex.[4-6] An investigation of the association between infraocclusion and dental anomalies in the current sample is presented in a separate paper.[7]

The prevalence of infraocclusion reported in the literature varies widely. Published studies include prevalences of 1.3% in 2,342 American school children of unspecified age; 8.9% in 1,059 Swedish children aged 3 to 12 years; and 24.8% in 1,530 Israeli children aged 2.5 to 13.5 years.[4,8,9] This wide variation in reported estimates may well relate to differences between studies in measurement approaches, e.g. direct visual examination or hand measurement on dental models, sample sizes, the ages of the subjects and criteria for defining infraocclusion.[9-11] There may be differences in prevalences between ethnic groups, but this is at present uncertain due to these confounding factors.[12]

Therefore, the main aim of this study was to determine the presence and extent of infraocclusion in samples comprising singletons and twins of European ancestry, in the late mixed dentition stage of development, using a new diagnostic method and objective criteria with two different patient records, panoramic radiographs and dental models. It was also aimed to determine the pattern of expression and how this may vary in relation to sex

(male/female), arch type (maxillary/mandibular), arch side (right/left) and tooth type (primary first molar/primary second molar).

Materials and methods

Samples

This study analysed data from two samples. The first sample comprised panoramic radiographs of 1,454 singleton Finnish children, of European ancestry, aged between 8 and 11 years. The radiographs were obtained during the years 1980-1997 by the Health Centre of Lapinlahti Council, Finland. The panoramic radiographs were then scanned and de-identified during 2006/07 at the Health Centre of Lapinlahti Council, Finland. Radiographs were excluded if there was any image distortion, permanent first molars were partially erupted, the primary tooth to be measured had a large restoration, there was significant loss of tooth structure due to caries and/or tooth wear, or if reference teeth were missing. The second sample comprised 270 dental models of Australian monozygotic (MZ) and dizygotic (DZ) twins of European ancestry, aged between 8 and 11 years. The zygosities of all of the twins included in the study have been confirmed as part of a larger ongoing investigation of dento-facial growth and oral health in Australian twins.[13-15] Dental models of twins were excluded if they were outside the age range of 8-11 years, if the models were damaged in any way, if primary teeth to be measured had a large surface restoration which interfered with the measurement criteria, if there was significant loss of tooth structure due to caries and/or tooth wear, or if there was any craniofacial malformation, e.g. cleft lip or palate. One member of each twin pair was randomly selected, using a random number generator, to avoid bias that could be introduced by including both members who share all

of their genes in the case of monozygotic pairs and half of their genes on average in the case of dizygotic twins. The study was approved by the University of Adelaide's Human Ethics Committee (Approval number: H-07-1984A).

Measurement method

Pilot study

A pilot study was conducted using a sub-sample of panoramic radiographs, in order to develop the technique and assessment criteria. Radiographs of 50 individuals, who were visually assessed and considered to display infraocclusion, as well as radiographs of 20 individuals who were visually assessed and considered to display no infraocclusion, were examined. Findings from the pilot study established high reproducibility of the measurement technique as reflected by the results of double determination analysis reported in the Results section.

Measurement using panoramic radiographs

Lädesmäki[16] has considered in detail the issues involved in making measurements from panoramic radiographs and noted that provided conditions are standardised carefully, as they were in this study, errors associated with patient positioning are small.

Adobe Photoshop CS5 computer software was used for constructing lines and measuring distances (in mm) between reference points, taking into consideration the magnification scale of the panoramic radiographs. To determine the 'occlusal plane', a line was extended from the mesial marginal ridge of the first permanent molar to the cusp tip of the primary canine (Figure 1). This was constructed to follow the orientation of the arch. The position of the mesial marginal ridge was determined by visualising where the base of the mesiobuccal

cusp ridge was located. Next, the 'occlusal table' of the primary first molars was constructed by drawing a line from the distal marginal ridge to the mesial marginal ridge of the primary first molar, using the base of the mesial and distal cusp ridges as landmarks. A similar line was constructed for the primary second molar (Figure 1). Following this, a line was drawn perpendicularly, from the mid-point of the 'occlusal table' to the 'occlusal plane', and this distance was measured (in mm).

Measurement using dental models

A 2D scanning system, adapted from that of Brook and colleagues[17] was used to obtain four images of the dental arch per individual; that is, images of both sides of the upper and lower dental arches. The presence and degree of infraocclusion was determined by using Photoshop CS5 computer software to construct lines between identified reference points and to measure selected distances (in mm), following the same methodology as for the images of panoramic radiographs (Figure 2).

Repeatability

To assess repeatability, duplicate measurements were compared within and between operators. Randomly selected sub-samples from both the panoramic radiographs and dental models (comprising approximately 10% of each sample group) were remeasured. Systematic errors were tested with paired t-tests and random errors quantified by calculating Dahlberg statistics.[18]

Once all measurements from the panoramic radiographs and dental models were obtained, data were categorised into the following groups: 'non-infraoccluded' (0-<1mm), 'mild' (1-<2mm), 'moderate' (2-<3mm) and 'severe' (≥3mm) infraocclusion.

Statistical analysis

Statistical analyses were performed using SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA) and IBM SPSS Version 20. Preliminary analyses of the data, including plotting of the data, showed skewness to the right associated with a high frequency of zero values, that is, 'non-infraoccluded' cases. This was followed by introducing a cut-off at a measurement of 1mm; that is, only measurements that were equal to or greater than 1mm were considered to represent infraoccluded teeth. The obtained measurements were then grouped into categories of mild (1 - <2mm), moderate (2 - <3mm) and severe (≥3mm) infraocclusion. Chi-square tests were carried out to compare the frequency of occurrence and degree of expression of infraocclusion according to sex, arch type, arch side and tooth type. Four-by-four contingency tables were constructed to examine the distribution of infraocclusion between sides within individuals. The values falling on the diagonal represented symmetrical expression of infraocclusion, while those values off the diagonal represented asymmetrical expression. Percentage concordances were also calculated to quantify bilateral occurrence of infraocclusion.

Results

Repeatability

Intra- and inter- operator comparisons of infraocclusion in the samples of panoramic radiograph and dental models revealed no systematic differences between measurements ($P>0.05$). Dahlberg values ranged from 0.04 to 0.10 mm, indicating that random errors were small and unlikely to bias the results.

Prevalence of infraocclusion

The prevalence in the maxillary arch was low in both samples, 0.8% (n=12, panoramic radiographs) and 0.7% (n=2, dental models). A summary of the prevalence of infraocclusion in the singleton and twin samples for both the maxilla and mandible is presented in Table 1. This table shows the frequency of occurrence of at least one infraoccluded tooth per individual in each sample. The prevalence of infraocclusion in the maxilla was less than 1%, whereas the prevalence in the mandible was 22% in the singleton sample and 32% in the twin sample.

Analysis of the singleton sample

Comparison of the prevalence and the degree of expression of infraocclusion according to sex was carried out in the singleton sample by conducting chi-square tests. The tests were done for each tooth separately. No statistically significant differences were found between males and females in the distribution of the four categories of infraocclusion in any of the teeth examined (Table 2).

A significant difference was present in the expression of infraocclusion between the primary mandibular first and second molars on both left and right sides, in both males and females ($P<0.01$). A greater number of cases of mild infraocclusion was noted in the primary mandibular first molar compared to the primary mandibular second molar. There were three cases of severe infraocclusion affecting the primary mandibular right first molar and one case affecting the primary mandibular left first molar but no cases of severe infraocclusion affecting the primary mandibular second molar in singletons in late mixed dentition stage of development (Table 2).

When the pattern of expression of infraocclusion in the mandibular molars, including individuals with no infraocclusion, was compared between right and left sides within each

individual, a significant association was shown to be present between sides, for both molars, in both sexes (P<0.001) (Table 3). Of the total affected cases that were categorised as mild, 94 cases had infraocclusion affecting both sides, 51 in males and 43 in females, while the remaining 229 cases (primary first molar, 149 cases; primary second molar, 80 cases) showed mild infraocclusion on one side and no infraocclusion on the other side. There were no cases within the moderate or severe categories that occurred bilaterally in individuals (Table 3).

Analysis of the twin sample

The same variables were also tested in the twin sample (Table 2). There was no statistically significant difference between males and females in the distribution of the four categories of infraocclusion in any of the teeth examined (Table 2). A significant difference was found in the distribution of infraocclusion categories between the primary mandibular first and second molars, for both arch side and sex (P<0.05).

When the pattern of expression of infraocclusion in the mandibular molars, including individuals with no infraocclusion, was compared between right and left sides within each individual, a significant association was shown to be present between sides, for both molars, in both sexes (P<0.001)(Table 4). Of the total affected cases that were categorised as mild, 28 cases had infraocclusion affecting both sides, 11 in males and 17 in females, while the remaining 72 cases (primary first molar, 31 cases; primary second molar, 41 cases) showed mild infraocclusion on one side and no infraocclusion on the other side. There were very few cases within the moderate (5 cases) or severe (5 cases) categories that occurred bilaterally in individuals in late mixed dentition stage of development (Table 4).

Discussion

A standardised approach with objective criteria for measuring infraocclusion has been developed and applied to singleton and twin samples with two different patient records, panoramic radiographs and dental models. In general, this technique was shown to have a high degree of reproducibility, allowing accurate measurements to be obtained. Some difficulties occurred when obtaining measurements in the maxillary arch in both samples. These difficulties included the repeatability of identification of the same reference points on the radiographs and the estimation of the curvature of the maxillary arch on the dental models. Therefore, detailed data for the mandibular arch only are presented in this report. The definition of infraocclusion in this study as being a tooth 1mm or more below the plane of occlusion is consistent with a number of published studies.[10,19-21] The narrow age range of 8 to 11 years old, with all subjects being in the late mixed dentition phase, was selected for the samples to minimize variation in prevalence of infraocclusion that could arise due to differences in age. A discrepancy in the prevalence of infraocclusion has been reported among different age groups confirming that infraocclusion prevalence is age specific.[10] Hence, different factors that could affect estimates of the prevalence of infraocclusion, such as measurement technique, definition of infraocclusion and selection of an age group, were controlled.

Differences in the prevalence of infraocclusion were noted between the two samples studied: in the singleton sample, the prevalence of infraocclusion was lower (22%) than in the twin sample (32%). A contributing factor to this variation could be the difference in the sample sizes included in this study (1454 panoramic radiographs of singletons compared to 270 dental models of twin pairs). Another possible contributing factor may relate to the different methods of data acquisition. For example, 2D photographic images of study

models allowed more precise outlines of teeth to be visualized in the twin sample compared with panoramic radiographs in the singleton sample, where tooth outlines tended to be less distinct. Nevertheless, double determinations confirmed that the measurement methods used for both samples had high repeatability and precision. The greater prevalence of infraocclusion in the twin sample may reflect distinct developmental features in twins compared to singletons. Some dental features, for example, smaller sized primary teeth, have been reported to be more common in twins with low birth-weight[22]compared to singletons with average birth-weight. The higher frequency of infraocclusion found in twins may be related to the associations between tooth size, low birth weight and delayed dental development[23] and to patterns of dental anomalies as suggested by Peck.[6] Based on these findings, further studies in this area are warranted.

Although the prevalence differed between the singleton and twin samples, the patterns of infraocclusion within each sample were similar. The primary mandibular first molar was infraoccluded significantly more often than the primary mandibular second molar in both samples. There was no significant difference in the prevalence of infraocclusion between males and females or between right and left sides in either sample, consistent with findings reported previously.[10]

Conclusion

The current investigation has developed a new standardised technique with objective criteria for measuring infraocclusion with high reproducibility as shown by the double determinations. Investigation of the patterns of infraocclusion showed no sex predilection for infraocclusion. The condition occurred more frequently in the mandibular arch. There

was no significant association between infraocclusion and arch side. The primary mandibular first molar was the most commonly infraoccluded tooth in both samples. The new technique developed in this study, and associated findings, may be utilized to enhance the early diagnosis of dental developmental abnormalities and treatment planning during late mixed dentition stage of development.

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Tables

Table 1: Summary of the prevalence of infraocclusion in the singleton and twin samples

Arch	Sex	Singletons		Twins	
Maxilla					
	Male	8/768	1.0%	2/144	1.4%
	Female	4/686	0.6%	0/126	0.0%
Total		12/1454	0.8%	2/270	0.7%
Mandible					
	Male	179/768	23.3%	51/144	35.4%
	Female	141/686	20.5%	35/126	27.5%
Total		320/1454	22.0%	86/270	32.0%

Only individuals with at least one infraoccluded molar included

Table 2: Comparison of the frequency of occurrence and degree of expression of infraocclusion between males and females – in singleton and twin samples

	Singletons		Twins	
	Primary First Molar		**Primary First molar**	
Degree of expression	***Right*** **m% / f%** **nm / nf**	***Left*** **m% / f%** **nm / nf**	***Right*** **m% / f%** **nm / nf**	***Left*** **m% / f%** **nm / nf**
Non-I	84.8%/85.5% 521/443	82.4%/81.5% 518/419	81.3%/80.3% 100/99	76.9%/75.2% 100/94
MI	14%/12.74% 87/66	15.9%/17.5% 100/90	13.8%/12.2% 17/15	17.7%/19.2% 23/24
MO	0.65%/1.54% 4/8	1.4%/0.10% 9/5	1.6%/4.9% 2/6	3.9%/2.4% 5/3
SE	0.32%/0.91% 2/1	0.16%/10.0% 1/0	3.3%/2.4% 4/3	1.5%/3.2% 2/4
Total	100%/100% 614/518	100/100 628/514	100%/100% 123/123	100/100 130/125
	Primary Second Molar		**Primary Second Molar**	
Non-I	95%/94.8% 679/604 4.5%/4.4%	93%/94% 670/600 6.5%/5.5%	84%/86.3% 121/104 12.5%/12.2%	82.9%/80.7% 120/100 12.5%/16.6%

MI	32/28	47/35	18/17	19/22
	0.55%/0.78%	0.6%/0.3%	2.8%/1.4%	3.3%/1.4%
MO	4/5	4/2	4/2	2/2
	0%/0%	0%/0%	0.7%/0.0%	1.3%/1.4%
SE	0/0	0/0	1/0	2/2
	100%/100%	100/100	100%/100%	100%/100%
Total	715/637	721/637	144/123	143/126

Non-I=non-infraoccluded, MI=mild, MO=moderate, SE=severe, m=male, f=female
nm=number of males, nf=number of females
No significant differences between sexes in the distribution of infraocclusion categories in either singletons or twins.

Table 3: Comparison of the frequency of occurrence and degree of expression of infraocclusion, between right and left sides within individuals, for the primary mandibular molars in singletons

First Molar	Degree of expression	Right m/f				
		Non-I	**MI**	**MO**	**SE**	**Total**
Left m/f	**NI**	448/374	38/23	0/2	0/0	486/399
	MI	47/41	39/32	3/5	0/1	545/79
	MO	2/1	5/3	0/0	2/0	9/4
	SE	0/0	0/0	1/0	0/0	1/0
	Total	497/416	82/29	4/7	2/1	585/453
Second Molar	**Degree of expression**	**Right m/f**				
		Non-I	**MI**	**MO**	**SE**	**Total**
Left m/f	**NI**	638/567	16/13	1/2	0/0	655/582
	MI	30/21	12/11	3/2	0/0	45/34
	MO	1/0	3/2	0/0	0/0	4/2
	SE	0/0	0/0	0/0	0/0	0/0
	Total	669/588	31/26	4/4	0/0	704/618

Non-I=non-infraoccluded, MI=mild, MO=moderate, SE=severe
m=male, f=female
Significant associations between sides for both molars and both sexes ($p<0.001$).

Table 4: Comparison of the frequency of occurrence and degree of expression of infraocclusion, between right and left sides within individuals, for the primary mandibular molars in twins

First Molar	Degree of expression	Right m/f				
		Non-I	MI	MO	SE	Total
Left m/f	NI	87/86	5/5	1/2	0/0	93/93
	MI	13/8	7/9	0/2	1/0	21/19
	MO	0/1	3/0	1/2	1/0	5/3
	SE	0/0	0/1	0/0	2/3	2/4
	Total	100/95	15/15	2/6	4/3	121/119
Second Molar	**Degree of expression**	**Right m/f**				
		Non-I	**MI**	**MO**	**SE**	**Total**
Left m/f	NI	99/87	10/7	1/0	0/0	110/94
	MI	11/13	4/8	0/1	1/0	17/22
	MO	0/0	1/1	1/1	0/0	2/2
	SE	0/0	1/0	1/1	0/0	2/1
	Total	110/100	16/16	3/3	1/0	131/119

Non-I=non-infraoccluded, MI=mild, MO=moderate, SE=severe
m=male, f=female
Significant associations between sides for both molars and both sexes ($p<0.001$).

Legends to figures

Figure 1. Method used to obtain infraocclusion measurements from the panoramic radiographs (singleton sample)

Figure 2. Method used to obtain infraocclusion measurements from the dental models (twin sample)