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Classification, reproducibility and prevalence of root proximity in periodontal patients

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Abstract

Aim: The primary aim of this study is to define and classify root proximity. The secondary aim is to examine the reproducibility of the measurement tools, to study the prevalence per inter-dental area and to examine whether the distance from the cemento-enamel junction (CEJ) to the bone crest (BC) differs between sites with root proximity and their contra-lateral sites without root proximity.

Material and Methods: In order to indicate the location of root proximity, a modification of the Shei ruler was developed, dividing the roots into three equal parts.

A radiographic template was used to measure the distance between the roots, in this way determining the severity of the root proximity. The reproducibility of the measurement tool was tested, the prevalence was calculated and the distances CEJ–BC for root proximity sites and contra-lateral sites were recorded.

Results: A two-digit classification was obtained dividing the root into three locations [apical (A), between (B) and coronal (C)], with each location having the possibility of three different severities of root proximity. The described modification of the Shei ruler and the measurement tool for the severities can be considered as reproducible measurement tools. Root proximity was most prevalent in maxillary molars and between central and lateral incisors in the maxilla and mandible. There was no difference in CEJ–BC distance between the root proximity sites and their contra-lateral sites.

Conclusion: We can conclude that a two-digit classification for root proximity was established. Root proximity in untreated periodontal patients has no influence on the distance CEJ–BC. However, the location of root proximity becomes important from the moment that periodontal disease has been established at that site. The severity of root proximity is important for choosing treatment options. There is a striking similarity between bone loss patterns and tooth loss and the location of inter-dental spaces where root proximity is most prevalent.

Key words: application; classification; definition; inter-dental space; location; periodontal patients; prevalence; root proximity; severity

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For those of us working in dental practice, it is often apparent that the roots of two separate teeth are positioned so close to each other that aesthetic results in bridgework or periodontal treatment are compromised or even impossible. Trossello & Gianelly (1979) used the term ''root proximity'' to describe those situations where roots of adjacent teeth are 1.0 mm or less apart, as measured radiographically. Root proximity was determined as favourable when there was more than 1 mm of bone between the roots and unfavourable when less than 1 mm was recorded. Kramer (1987) describes 1 mm as a minimum to achieve adequate septal space between the roots. In a study by Årtun et al. (1986), root proximity was diagnosed when roots were closer than 0.8 mm together on peri-apical radiographs. None of these studies, however, explained the used cut-off points. Heins & Wieder (1986) performed a histologic study on the width and nature of inter-radicular spaces and found that the minimal inter-root distance, at the site of the closest proximity of the roots in an inter-dental space, ranged between 4 mm and less than 0.1 mm. Cancellous bone flanked by lamina dura was observed where the inter-root distances exceeded 0.5 mm. At sites less than 0.5 mm, cancellous bone

was not observed and instead, adjacent lamina durae appeared fused. Bone was not observed between surfaces that were less than 0.3 mm apart, but in these instances the roots were connected with the periodontal ligament. The close approximation of roots can also be seen in furcations. Bower (1979) reported that 81% of the furcation entrances are smaller than 1.0 mm and 58% of the furcation entrances are smaller than 0.75 mm. The curettes that are used for scaling and root planing usually vary between 0.75 and 1.1 mm. This is the reason why we can assume that proper instrumentation of the roots cannot be achieved if they are closer than 0.8 mm from each other. Also, Chiu et al. (1991) reported this for a Chinese population in maxillary and mandibular first molars. They found furcation entrances to be smaller than 0.75 mm in 49%. They suggested two things to improve instrumentation, i.e. sharpening curettes to narrow the blade width or using an ultrasonic tip that has a 0.5 mm diameter at the terminal end.

Classifications are generally based upon specific morphologic criteria and are aimed at guiding the clinician with diagnosis, treatment plan and prognosis. The extent to which the classification method for root proximity will yield reproducible data must be established, because a number of factors may have a negative effect on the reproducibility (e.g. inaccuracy in placing the modified Shei ruler (Shei et al. 1959) or the gridlines to examine thickness, individual ability in judging a radiographic image, experience).

A poorly shaped gingival embrasure is almost always a result of the shape of the crowns and the proximity of the roots (Goldman et al. 1973, Olsen 1985). This can jeopardize the health of the inter-proximal space (Wheeler 1958, Waerhaug 1980, Nevins 1982) and can even lead to more rapid periodontal breakdown (Klassman & Zucker 1969). It has also been suggested that the inter-dental septum, which consists of two layers of cortical bone, has a low regenerative capacity (Ritchey & Orban 1953), which in turn might lead to horizontal bone loss. Other studies state that the horizontal pattern of bone loss is because of the course of the blood vessels in the thin septum (Akiyoshi & Mori 1967, Kramer 1987). As far as we know, no study has attempted to investigate the prevalence of root proximity in untreated periodontal patients or to evaluate the severity or location of root proximity using a classification. The primary aim of this study was to define and classify root proximity in a way that encompasses the part of the root affected and also the width of the remaining interradicular tissue between the two involved roots. A secondary aim was to test the reproducibility of the measuring method. A tertiary aim was to apply the method in order to see in which inter-dental sites root proximity was more prevalent and to calculate whether there was a difference in the distance from the cemento-enamel junction (CEJ) to the bone crest (BC) of sites with root proximity compared with their contra-lateral site without root proximity.

Material and Methods

Subjects

One hundred and ninety-seven consecutive patients of several operators, working in the Catholic University of Nijmegen and in private practice, were selected for the study group. All operators were following the same philosophy and strategy in both the university and their private practice. All subjects, fulfilling the inclusion criteria, which were examined by one of the operators between September 1997 and June 2001, were included in the study. The inclusion criteria to participate in the study group were the following: the patients were periodontal patients with advanced periodontal disease with bone loss more than one-third of the root length at atleast one site, patients were required to have all (28) teeth in order to be included in the study, no fixed orthodontic treatment should be performed in the past and third molars could be present but were not examined in the study. For each patient a full-mouth radiographic examination was carried out, taken with the long-cone technique, consisting of at least one radiograph of the molars in each sextant, one of the pre-molars in each sextant and three radiographs in the frontal area of each jaw in order to compensate for the inaccuracy because of the angulation of the X-ray beam.

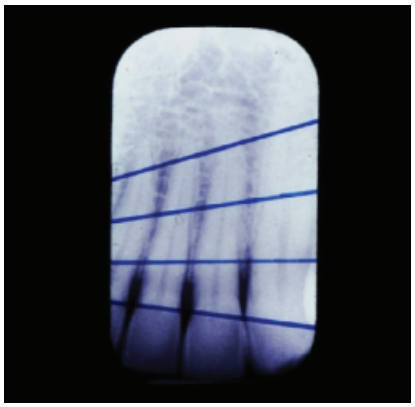
The patients in the study group were aged between 18 and 66 years (average of 42 years). Eighty-two were men and 115 were women.

Radiographic measurement and classification

Every inter-proximal space was assessed on full-mouth radiographs and a score was assigned according to severity and location.

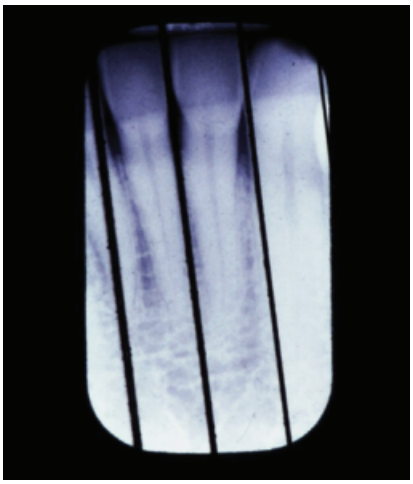
Division: to indicate location

For indicating the location, a modification of the Shei ruler (Shei et al. 1959) was used. The modification consisted of the use of four lines that were divergent with an equal degree. The ruler was placed over the teeth so that one outer line contacted the shortest root at the apex and the other outer line contacted the most apically placed CEJ (Picture 1), dividing the roots into three equal parts.



Subdivision: to indicate severity

The distance between the roots determines the severity. On the radiographs, a template with four lines, having the thickness of 0.3, 0.5, 0.8 and 1.0 mm, was placed parallel with the two roots bordering the inter-dental space (picture 2). The thickest line that could be fitted between the area where the two roots were the closest together, without overlapping one of the roots, determined the classification. If the line with 1.0 mm thickness could be fitted in the inter-dental area without covering the bordering roots, root proximity was scored as 0 in that inter-dental space. The cut-off points were based on the histologic findings of Heins &Wieder (1986). If the same inter-dental space was present on several radiographs, the assessed radiograph was the one where the root proximity was the least severe. In this way, the inaccuracy because of the angulation of the X-ray beam was compensated for.



Reproducibility

A subgroup of 20 alphabetically selected subjects with advanced periodontal disease, who were part of the study group, were examined. These subjects were aged between 23 and 67 years (average of 41 years). Twelve were men and eight were women. Four operators accomplished a training period that lasted for 30 min. and consisted of explanation of the classification and method of using the measurement tools. Two experienced periodontists (examiner one and three) and two general dentists (examiner two and four) examined the 20 radiographs. The four examiners were isolated from each other and time for examining the radiographs was unlimited. Every inter-dental space of the 20 radiographs was examined, and the location and severity of root proximity were recorded. One of the examiners investigated the same sets of radiographs two times, once as part of the inter-examiner reliability testing and a second time 3 months later when the application of the measurement tools was examined.

Application of the measurement tools

Prevalence of root proximity

All 197 patients each had 26 inter-dental spaces that were examined for root proximity, specified in severity and location (part II of the study). The prevalence of root proximity was examined and ordered according to the inter-dental space where it was present.

Distance CEJ–BC

In addition, the distance between the most apical CEJ and the BC was measured in millimetres at the sites with root proximity by using a ruler with increments of 1 mm. At sites where the BC was located in an area with root proximity severity 3, the most coronal position of the bone of the involved teeth was measured.

Statistical analysis

The reproducibility between the four examiners and intra-examiner agreement was tested using weighted κ and recorded. The score was weighted 1 when there was complete agreement; it was scored 0.67 when there was one severity difference and 0.33 when there were two severities difference. For measuring the difference of the distance CEJ–BC of the root proximity sites with their contra-lateral sites a paired *t*-test was performed.

Results

A two-digit classification was obtained dividing the root into three locations, with each location having the possibility of three different severities of root proximity.

Division: to indicate location (Picture 1)

C(oronal)
B(etween)
A(pical)

The division of the root surface, bordering the inter-proximal area, into three equal parts was accomplished by using a modification of the Shei ruler. Root surfaces were divided into three equal parts: the coronal third (c), the intervening third (b) and the apical third (a). When present, root proximity was scored as being in the coronal, middle or apical portions of the roots or a combination of the locations.

Subdivision: to indicate severity (Picture 2)

Severity 1: >0.5 and $\leqslant 0.8$ mm: small amount of cancellous bone is present between the adjacent roots.
Severity 2: >0.3 and $\leqslant 0.5$ mm: only cortical bone and connective tissue attachment is present between the adjacent roots.
Severity 3: $\leqslant 0.3$ mm: only connective tissue attachment is present between the adjacent roots.

In this way every inter-proximal area with root proximity was assigned with one category of location and one category of severity obtaining a two-digit classification for each inter-proximal area where root proximity was present.

For an inter-dental space between a first and second molar, the classification could appear as follows: 16–17: C2 B3 A1 or 16–17: C3A3 if there is no root proximity in the intervening part.

Reproducibility

Every examiner examined 20 full-mouth radiographs using the modified Shei ruler and the gridlines for measuring the thickness.

When comparing examiners two and three with examiner four, the agreement is good, with the weighted κ being between 0.53 and 0.65 (Table 1).

When comparing examiners two and three, the agreement is very high, with the weighted κ being between 0.91 and 0.94. The inter-examiner agreement of examiner one with the others was poor.

Table 1. Inter-examiner agreement between four independent examiners and intra-examiner agreement for examiner two, for the three different locations and expressed in weighted κ

Location	Examiner	1	2	3	4
a	1		0.58	0.63	0.54
b			0.48	0.5	0.46
c			0.47	0.49	0.48
a	2	0.58	0.94	0.94	0.94
b		0.48	0.93	0.91	0.91
c		0.47	0.92	0.91	0.91
a	3	0.63	0.94		0.57
b		0.5	0.91		0.65
c		0.49	0.91		0.61
a	4	0.54	0.94	0.57	
b		0.46	0.91	0.65	
c		0.48	0.91	0.61	

Intra-examiner agreement was very high with the weighted κ between 0.92 and 0.93.

Prevalence of root proximity

Root proximity in the maxilla is most prevalent between the first and second molar and between the central and lateral incisors, both approximately to an equal degree unilateral or bilateral (Fig. 2). In the mandible, root proximity is most prevalent between the central and lateral incisors, again approximately to an equal degree unilateral or bilateral and between the central incisors (Fig. 1). Of all the 5122 inter-dental spaces, 785 have root proximity and 535 (68%) of them are located in the maxillary molars or between the central and lateral incisor or between the incisors in the mandible. In all the other inter-dental spaces in the maxilla and mandible, root proximity is much less present and generally unilaterally distributed.

Distance CEJ–BC

The average distance CEJ–BC of sites with root proximity in at least the coronal part [4.14 mm (SD 1.87)] was not significantly different ($p = 0.80$) from the contra-lateral site without root proximity [4.15 mm (SD 1.66)].

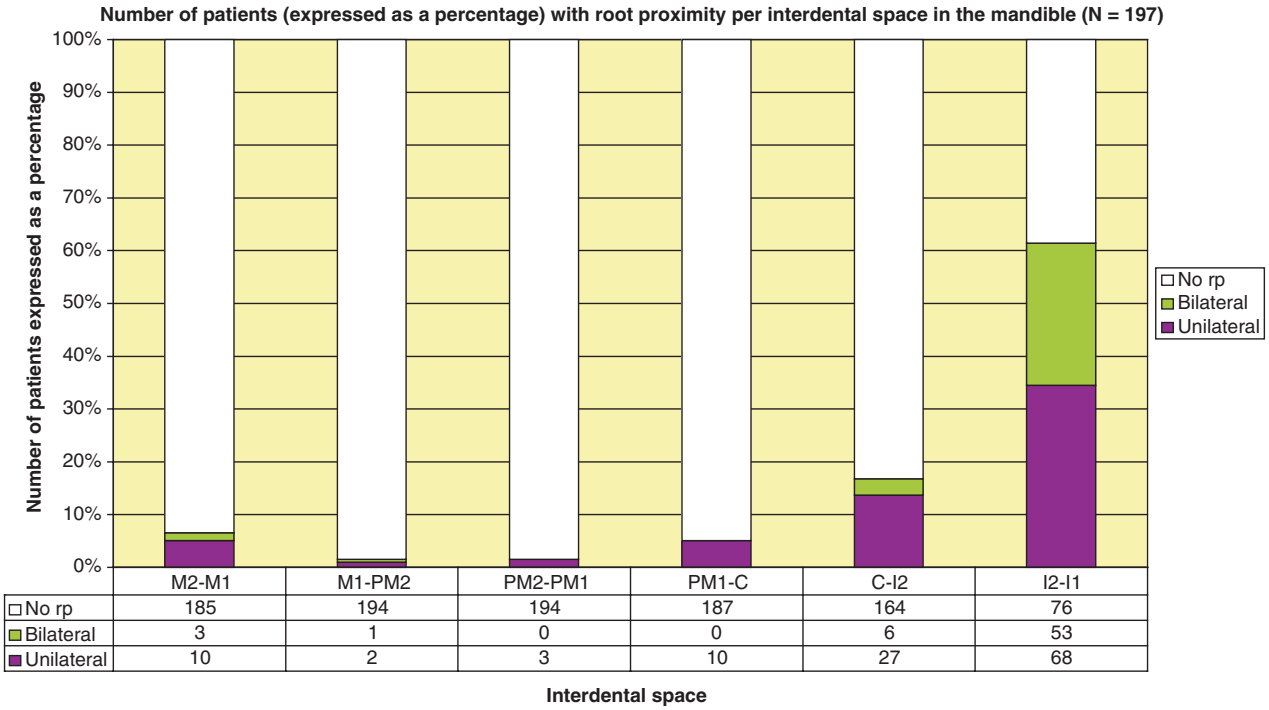
Discussion

One of the inclusion criteria of the study is for the patients to have a full dentition (28 teeth). The phenomenon ''root proximity'' is such that it can only be examined if all the teeth are present; otherwise, there would be an underestimation of root proximity. Nevertheless, it is possible that patients with very severe periodontal disease were not included in the study because they would have undergone extractions before referral to the periodontist. According to Hirshfield &Wasserman (1978), 29% of the subjects with periodontal disease who were treated still had more than 28 teeth after initial treatment.

One might question the applicability of two-dimensional radiographs to classify a three-dimensional phenomenon. Tibbets et al. (1992) examined the change of the periodontal ligament width with X-ray angulation. They stated that a change in X-ray angulation of more than 10° in a horizontal or vertical direction could result in different judgement of the periodontal ligament width. They concluded that a significant change could be observed in the incisor location only. In the present study all the radiographs were taken using the long-cone technique, which would virtually eliminate the chance of angulations of more than 10°. In addition, in order to compensate for horizontal angulation changes of X-ray beams, the examiner took care to assess every inter-dental space on different radiographs of the full-mouth X-ray status. The radiograph on which the root proximity was the least severe was counted for.

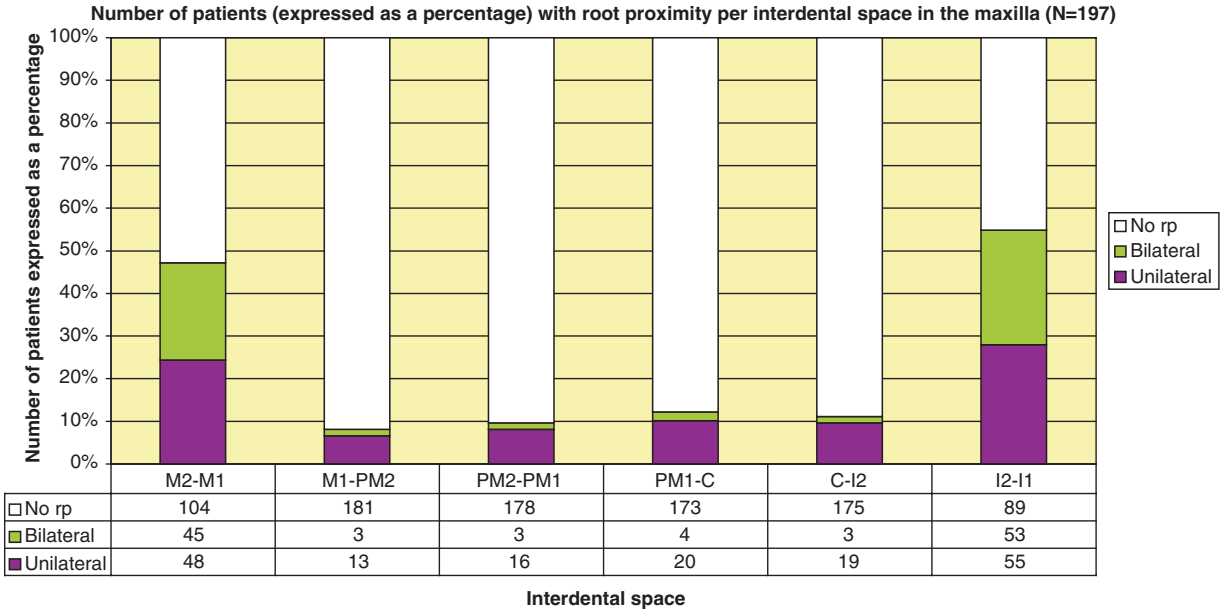
When recording the reproducibility of the measurement tools, the inter-examiner agreement between examiner one and the others was poor. After the examination, examiner one stated that in some cases he had difficulties in judging the radiographs and that the use of magnification might be useful. Because the inter-examiner agreement was fair to high for the other three independent examiners, it was not felt necessary for examiner one to repeat the recordings.

Because the study was cross-sectional, no conclusions could be drawn regarding bone loss over time in sites with root proximity. However, when we compare the distance CEJ–BC in sites with root proximity and their contra-lateral site without root proximity, it can be concluded that the site with root proximity had not experienced more bone loss in the past as compared with the contra-lateral site.



	M2-M1	M1-PM2	PM2-PM1	PM1-C	C-I2	I2-I1
No rp	185	194	194	187	164	76
Bilateral	3	1	0	0	6	53
Unilateral	10	2	3	10	27	68

Fig. 1. Number of patients (expressed as a percentage) out of a total of 197 with root proximity per inter-dental space in the mandible and split into unilateral, bilateral and no root proximity.



	M2-M1	M1-PM2	PM2-PM1	PM1-C	C-I2	I2-I1
No rp	104	181	178	173	175	89
Bilateral	45	3	3	4	3	53
Unilateral	48	13	16	20	19	55

Fig. 2. Number of patients (expressed in percentage) out of a total of 197 with root proximity per inter-dental space in the maxilla and split into unilateral, bilateral and no root proximity.

Sixty-eight percent of all the root proximities are located in the maxillary molars, between the central and lateral incisors or between the incisors in the mandible. These are exactly the teeth that are also more sensitive to bone loss and tooth loss (Hirshfield & Wasserman 1978, Laurell et al. 2003).

The location that is most likely to affect the dentist in performing his treatment, and the location that is most likely to affect the patient in performing his daily oral hygiene care, is the coronal part. Therefore, the coronal part is always mentioned before the intervening and apical part.

The question is how this classification can guide the clinician in making a treatment decision. Data of Chiu et al. (1991) and Bower (1979a, b) indicate that proper instrumentation of the roots cannot be achieved if the furcation entrances are smaller than the width of the curettes. A similar situation can be extrapolated when considering root proximity. The success of periodontal therapy is dependent on the effectiveness of scaling and root planing and surgical access in combination with meticulous oral hygiene (Kaldahl et al. 1996, Kalkwarf 1991). Therefore, it seems clear that these requirements cannot be fulfilled in case of severe root proximity in the coronal part or in the inter-proximal area that has been affected by periodontal disease. It is therefore logical to assume that periodontal treatment will be incomplete in these sites and that they might be more prone to future deterioration. If the latter occurs it may be advisable to eliminate the root proximity.

Orthodontic therapy has proven its benefits in the past [uprighting of mesially inclined molars (Brown 1973)] altering not only the appearance of the gingiva but also the oral hygiene level. Even minimal orthodontic movement can make the difference between a root surface that is debridable and one that is not. Therefore, orthodontic therapy has been suggested as a viable treatment option in case of root proximity (World Workshop in Periodontology 1989). If extensive prosthetic rehabilitation is scheduled, extraction of a non-strategic tooth or root with root proximity is also suggested (Giovanolli 1981).

If bone loss has not occurred, prevention and follow-up are indicated.

Although it might appear that interdental oral hygiene would be hindered by severe root proximity, the use of dental tape is possible even in interdental spaces with root proximity severity 3.

It should also be pointed out that root proximity could be prevented to a certain degree. Inter-proximal caries and the natural anterior compound of force will narrow the root distances and change the shape and compactness of the inter-proximal bone. Therefore, it is evident that large inter-proximal caries should be avoided and that meticulous restoration of the contact point is necessary (Mount & Hume 1998).

In conclusion, the described modification of the Shei ruler and the gridlines can be considered as a reproducible measurement tool for defining and classifying root proximity that can be used by experienced periodontists as well as by general practitioners.

Guided by the fact that, if roots are closer than 0.8 mm apart from each other, they are more difficult to treat periodontally and prosthodontically, we can state the following definition of root proximity:

Root proximity is the situation whereby there is 0.8 mm or less bone or interdental tissue present between the two involved roots.

A two-digit classification for root proximity was established, with three divisions of location (coronal, between and apical) and subdivisions of severity (severity 1, severity 2 and severity 3). The location of root proximity becomes important from the moment that periodontal disease has established there; the severity of root proximity is important for choosing treatment options. The inter-dental spaces that are in general more prone to bone loss are also the inter-dental spaces that experience more root proximity. Now the question arises as to whether there is a difference in the prevalence, severity and location of root proximity in periodontal patients as

compared with non-periodontally affected subjects.

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