Periodontal Bone Loss in Chinese Subjects with Untreated Early-Onset and Adult Periodontitis: A Cross-sectional Study Using Digital Scanning Radiographic Image Analysis

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The purpose of this investigation was to evaluate the differences in radiographic alveolar bone loss (RABL) in Taiwanese subjects with early-onset periodontitis (EOP) and adult periodontitis (AP) using the digital scanning radiographic image analysis (DSRIA). A total of 4,262 teeth from 178 individuals (96 males and 82 females) were examined for RABL due to EOP and AP. The subjects with EOP and a comparison group with AP were identified from the Periodontal Clinic population (College of Dental Medicine, Kaohsiung Medical University). The following criteria were used to classify subjects with EOP and AP during the past 20 years. The RABL of teeth were calculated using a computer system equipped with Microstation 95 software, under 10 X magnification of the radiographs. Quantity assessment of RABL using the DSRIA showed that: (1) the means of RABL of maxillary and mandibular anterior teeth in the EOP group were significant greater than those in the AP group when the two sample *t*-test was used. (2) The greatest values of mean RABL of affected sites in the EOP group occurred most commonly in the first molars and mandibular incisors, whereas, in the AP group, the greatest values of mean RABL of affected sites occurred most commonly in the first and second molars. (3) Molars had the greatest mean RABL followed by incisors, premolars and canines. (4) The mean RABL increased with increasing age. We conclude that the features of naturally progressing alveolar bone loss at the molar and incisor sites in untreated subjects with the EOP and AP revealed that the mean RABL in the EOP group was faster and greater than that in the AP group.

Key Words: digital image analysis, alveolar bone loss, early-onset periodontitis, adult periodontitis

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The majority of the cross-sectional and longitudinal studies employing different techniques relating to the rate of periodontal attachment loss in individuals with healthy periodontia, adult periodontitis (AP) and early-onset periodontitis (EOP) have been reported using mainly clinical probing and radiographic measurements. Understanding the epidemiology associated with different types of periodontitis, especially of EOP and AP among individuals reporting to the teaching hospitals, has been from retrospective study via clinical diagnoses [1]. Other reports on the

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prevalence, distribution and rate of alveolar bone loss were performed based on the longitudinal radiographic evaluation of clinically healthy individuals [2–4]. Only a few studies reporting the extent of alveolar bone destruction versus age, degree and location on patients with periodontitis have been published [5, 6]. Recently, Albandar et al investigated individuals with clinical classifications of periodontitis in adolescent and young adults and suggested that incidental, localized and generalized EOP are a heterogenous group of diseases with rapidly and slowly progressing forms [7]. They also concluded that a classification system of subsets of the disease that are defined according to a combination of cross-sectional criteria and disease progression may be useful for studies in EOP.

It is well known that there is little or no information regarding the degree, prevalence, location and extent of alveolar bone alterations related to age and gender in Chinese patients with AP and EOP. Furthermore, our previous studies revealed that there was considerably higher prevalence of periodontitis with molar furcation involvement in Chinese than in Caucasians due to the higher incidence of cervical enamel projections in molars [8] and palato-radicular grooves in incisors than in Caucasians [9]. Literature regarding the rate of periodontal attachment loss (PAL) in different aged subjects with established and EOP in cross-sectional and longitudinal studies addressed some great discrepancies with age and racial variations.

The purpose of this study was to evaluate the radiographic alveolar bone loss (RABL) rate in EOP and AP using digital scanning radiographic image analysis (DSRIA). In addition, RABL related to age, sex, tooth type and site in Taiwanese was also evaluated.

Materials and Methods

A total of 178 individuals (96 males and 82 females) with periodontitis were randomly selected from the patient population of the Periodontal Clinics Kaoshiung Medical University Dental School from 1980 to 1999. Their age ranged from 24 to 75 years (mean age, 43.1 yr). Of the 178 individuals, 25 had EOP and 153 had AP. The study evaluated factors such as gender, age, periodontal bone loss rate, tooth location and tooth mortality, which could influence the clinical characteristics and courses of EOP and AP. Subjects were recalled to determine the change and clinical course of their EOP and AP, regardless of whether or not they had received periodic periodontal therapy.

The subject population of the present study was limited to the untreated patients affected with AP and EOP. Before any treatment was undertaken, patients were examined clinically and radiographically. The criteria for sample collection comprised the following: 1) individuals have never received periodontal treatment (surgical or nonsurgical); 2) missing teeth were extracted due to periodontal causes; 3) subjects had no chronic systemic diseases (such as diabetes, hyper- or hypoparathyroidism). The clinical periodontal examination included age, sex, dental history (including causes of missing tooth and history of previous periodontal therapy), plaque index [10], gingival index [11], initial probing pocket depths and clinical attachment levels. Radiographs showing tooth distortion, poor quality, restoration obliterating the cemento-enamel junction (CEJ) and overlapping of either teeth or CEJ measurements, producing unreadable measurement points were excluded from the analysis.

Periapical radiographs were taken by the use of a parallel technique and XCP film holders with long cone indicators. Radiographic assessment of mesial and distal alveolar bone loss were recorded by scanning (Nikon LS-1000, Adaptec AHA-2940 UW SCSI card) the radiographs into a personal computer (Windows 98, Microsoft, Redmond, WA, USA) at 1,350 dpi (dots/inch) in 256 shades of gray. All the scanned radiographs were displayed on a PC monitor using 10 X image enlargement (Adobe Photoshop 5.0, Adobe Systems Incorporated, San Jose, CA, USA) and were assessed using Microstation 95 Image Software (MIS) (Windows x 86, Bently Systems, Inc., Exton, PA, USA).

Proximal RABL was defined as a bone defect in which the distance between CEJ and alveolar crest (AC) was at least 2 mm. Each tooth was measured mesially and distally. The radiographic images of the CEJ (A), AC (B) and root apex (C) were used as three reference points for the calculation of the radiographic linear measurements of RABL. The alveolar bone crest was recorded as the most apical point of each mesial or distal defect. The distances of AB (RABL) and AC (root length) were measured using DSRIA to determine the percentage of RABL. Duplicate measurements were obtained for each tooth. All the measurements were numerically coded, and the results were processed and analyzed by the computer system equipped with the MIS [12]. The means of RABL in both the EOP and AP were stratified into five age groups: below 31 years, 31–40, 41–50, 51–60 and above 60 years.

Reliability testing

The means of RABL measured by DSRIA for each molar tooth were compared for inter- and intra-examiner reliability. The means and standard deviations of the DSRIA measurements were used as the statistical values for the comparisons of each molar for the inter- and intra-examiner reliability calculations. The reliability coefficients were used to compare the consistency and reliability between the intra- and the inter-examiner's groups using the DSRIA values for each maxillary and mandibular tooth. A p-value of less than 0.05 was defined as statistically significant. The intra-examiner and inter-examiner reliability coefficients for measuring the RABL of maxillary, mandibular and of both molars using the DSRIA were ranged between 0.986 and 0.995, respectively [13]. Comparison of the inter- and intra-examiner's reliability coefficients demonstrated that the inter- and intra-class reliability coefficients in maxillary, mandibular, and of both molars were significantly different from zero ($p < 0.001$).

Data analysis

The means and standard deviations of the DSRIA measurement data for the comparisons of each tooth between the EOP group and AP group were analyzed.

Results

Mean RABL by age for maxillary teeth

Among the four age strata in the AP group, the mean RABL of maxillary teeth increased slightly in the age groups of 31–40 years (33.3 ± 10.8%), 41–50 (35.9 ± 13.0%), and 51–60 (36.8 ± 11.3%), while greatly different patterns were found in age groups of both EOP under 31 (42.5 ± 13.7% and AP over 60 years (29.5 ± 10.2%) (Table 1). The greatest amount of mean RABL was identified in either first molars (AP: age 31–40 yr, 49.7 ± 19.1%; 41–50 yr, 51.1 ± 20.5%; 51–60 yr, 52.1 ± 16.6%) or second molars (AP: age 31–40 yr, 35.0 ± 10.2%; 41–50 yr, 39.8 ± 12.9%; 51–60 yr, 45.5 ± 14.8%) in all age groups except the over 60 years group (33.0.0 ± 11.8%). In the AP group, maxillary first molars had the highest mean RABL, followed by maxillary second molars and maxillary central incisors, then premolars, and finally, canines (Table 1).

In the EOP group, maxillary first molars (56.5 ± 18.2%) had the highest RABL, followed by lateral incisors (51.9 ± 16.9%), central incisors (49.2 ± 12.4%), first premolars (49.5 ± 11.7%) and central incisors (47.4 ± 14.7%). Notably, the means of RABL were greater for maxillary first molars (56.6 ± 18.2%) and lateral incisors (51.9 ± 16.9%) in the EOP as compared to that in any age group of the AP group.

Mean RABL by age for mandibular teeth

The mean RABL of mandibular teeth gradually increased with increasing age in patients aged 31–40 years (32.8 ± 11.3%), 41–50 years (37.2 ± 14.3%), 51–60 years (39.3 ± 13.5%) and over 60 years (43.8 ± 14.1%), similarly to maxillary teeth (Table 2). The greatest mean RABL in AP was identified in either first molars or incisors of any age group.

Individuals with EOP in the less than 31 years age group had greater mean RABL (37.1 ± 12.7%) compared to the AP group of age 31–40 years (32.8 ± 11.3%).

A remarkably greater mean RABL occurred in the over 60 years age group (43.8 ± 14.1%) compared to the same age group within the EOP (37.1 ± 12.7%) and any age group (32.8 ± 11.3% for 31–40 yr to 39.3 ± 13.5% for 51–60 yr) in the AP group. The greatest means of RABL were noted for the central incisors (64.6 ± 19.5%), lateral incisors (51.6 ± 15.7%) and second molars (50.2 ± 16.1%).

In the AP group, the first molars had the highest RABL, followed by the central and lateral incisors, and second molars; canines had the least RABL, except in the over 60 years age group.

Mean RABL differences between maxillary and mandibular teeth

The means of RABL were remarkably higher in maxillary teeth than in mandibular teeth for each age group, except the over 60 years age group. In addition, the mean RABL of mandibular incisors were remarkably higher when compared to maxillary incisors, irrespective of the age group, except for the under 31 years group in EOP patients.

The means of RABL at molar sites were greater in maxillary teeth in any age group for EOP and AP, except for the AP in the over 60 years age group. The means of RABL for incisors were greater for mandibular incisors compared to maxillary incisors, with the exception of the EOP group.

For teeth in both dental arches, maxillary first molars had the highest RABL, followed by maxillary second molars and mandibular central incisors, and premolars; mandibular canines had the least RABL, except for the over 60 age group.

Tooth mortality by age group and tooth type

The tooth mortality rate was higher for molars and incisors than for other teeth in both arches. In general, tooth mortality rate tended to increase with increasing age in both arches. The highest tooth mortality rate was found in the over 60 years age group, especially for maxillary first (59.4%) and second (40.6%) molars. The highest tooth mortality rate of mandibular teeth was noted in the 51–60 years age group (Table 4) . Based on tooth type for all age groups and for both EOP and AP, the increase in the number of teeth lost with increasing age was most pronounced for maxillary first and second molars, accounting for 4.2% to 40. 6% loss and 8.3% to 59.4% loss, respectively (Table 3).

Higher tooth mortality occurred in mandibular teeth than in the maxillary teeth. The descending order of ranking by frequency of tooth loss is shown in Table 3. The maxillary first molars (59.4%) and mandibular second molars (46.2%) were the teeth most frequently lost, followed by maxillary second molars (40.6%), mandibular first molars (38.9%), maxillary second premolars (31.3%), mandibular first premolars (28.1%) and incisors. Canines had the lowest mortality rate (Tables 3 and 4).

Discussion

DSRIA for the measurement of proximal alveolar bone loss was highly reliable. Thus, we obtained more accurate RABL measurements compared to those performed by traditional methods, as were those reported earlier [1–4].

In general, the observations from our study showed the greatest amount of mean RABL in either arches of molars and mandibular incisors. Similar findings have been well documented in other studies [14–20]. Our results support the earlier agreement that molars and incisors are the most susceptible to periodontal breakdown. Based on this, it is necessary that the clinician pays close attention to these important sites of potential periodontal breakdown at each recall appointment. Nonetheless, Papapanou et al reported that the lowest rate of bone loss occurred in mandibular molars [18].

Among subjects with AP in our study, the mean RABL gradually increased with increasing age, except for those over 60 years of age. This finding was in agreement with most other reports [1, 15, 18, 19, 21].

Among subjects with EOP under the age of 31 years, significantly greater mean RABL occurred in maxillary teeth (42.5 ±_13.7 %) compared to the other four age groups (Table 1). A possible reason might be that several subjects highly susceptible to EOP were included in this small group. Our charts revealed that the EOP subjects with the most severe alveolar bone loss in all teeth, with molars and incisors being most

Table 1. Difference of mean RABL of tooth type in the maxillary arch of both the EOP and the AP by age groups (yr)

Tooth location	EOP (age < 31)		AP (age 31–40)		AP (age 41–50) RABL (%)		AP (age 51–60)		AP (age > 60)	
	mean (SD)	n	mean (SD)	n	mean (SD)	n	mean (SD)	n	mean (SD)	n
17 & 27	36.9 (12.6)	23	35.0 (10.2)	156	39.8 (12.9)	65	45.5 (14.8)	33	33.0 (11.8)	19
16 & 26	56.6 (18.2)	22	49.7 (19.1)	137	51.1 (20.5)	61	52.1 (16.6)	37	24.3 (8.1)	13
15 & 25	29.1 (10.1)	23	31.0 (12.1)	146	32.2 (11.3)	73	33.2 (10.4)	46	34.5 (11.6)	22
14 & 24	49.5 (11.7)	22	31.4 (11.3)	151	36.9 (13.4)	74	37.6 (11.3)	49	38.1 (13.2)	25
13 & 23	31.4 (8.3)	23	19.9 (5.6)	157	22.9 (7.4)	79	23.8 (6.7)	51	26.7 (8.4)	29
12 & 22	51.9 (16.9)	23	29.7 (8.4)	142	34.4 (12.2)	78	35.2(10.9)	47	24.6 (8.3)	28
11 & 21	47.4 (14.7)	22	32.3 (9.4)	140	38.5 (14.9)	73	38.8 (11.2)	46	26.0 (9.1)	28
mean (SD)	42.5 (13.7)	158	33.3 (10.8)	1029	35.9 (13.0)	503	36.8 (11.3)	309	29.5 (10.2)	164

SD = standard deviation; n = number of teeth examined.

Table 2. Difference of mean RABL of tooth type in the mandibular arch of both the EOP and the AP by age groups (yr).

Tooth location	EOP (age < 31)		AP (age 31–40)		AP (age 41–50) RABL (%)		AP (age 51–60)		AP (age > 60)	
	mean (SD)	n	mean (SD)	n	mean (SD)	n	mean (SD)	n	mean (SD)	n
37 & 47	34.8 (12.6)	24	31.8 (12.3)	130	38.7 (13.1)	69	42.9 (14.6)	29	50.2 (16.1)	22
36 & 46	51.3 (17.2)	22	46.6 (16.1)	108	48.9 (17.3)	55	49.7 (17.8)	3	48.7 (15.4)	26
35 & 45	33.9 (11.4)	23	26.6 (10.7)	148	28.6 (12.3)	72	34.5 (12.1)	39	33.5 (10.2)	27
34 & 44	33.8 (9.2)	23	28.5 (7.8)	156	30.4 (11.1)	74	31.2 (10.8)	43	29.1 (10.1)	23
33 & 43	30.0 (10.1)	24	21.2 (9.2)	161	27.9 (10.6)	79	29.1 (9.7)	51	29.9 (11.6)	29
32 & 42	42.9 (13.5)	22	38.3 (11.7)	149	40.8 (16.7)	72	42.2 (14.5)	47	51.6 (15.7)	27
31 & 41	49.2 (12.4)	19	39.7 (12.6)	143	41.8 (18.9)	63	48.0 (16.7)	41	64.6 (19.5)	26
mean (SD)	37.1 (12.7)	157	32.8 (11.3)	995	37.2 (14.3)	484	39.3 (13.5)	283	43.8 (14.1)	180

SD = standard deviation; n = number of teeth examined.

severely affected, were in the under 31 years of age group. In contrast, another eight subjects revealed typical, stable, localized AP. Other studies also pointed to EOP being a largely generalized disease in the 20–30 year age range, and concluded that the disease rapidly developed generalized destruction with increasing age [22–24]. Our results for subjects with EOP under 31 years of age appear to be in agreement with this disease concept. The ages of our subjects with EOP (including rapidly progressive periodontitis and generalized juvenile periodontitis) was greater compared to those with the localized pattern of juvenile periodontitis (onset at age 12 yr) and AP (onset at over 31 yr of age) [22–24]. Among subjects in the EOP group, maxillary first molars or lateral incisors were much more severely affected (had greater RABL) in those under 31 years of age compared to the other four age groups (Table 1). This pattern of disease progression is well in agreement with the conclusions of Okamoto et al [16] and Lindhe et al [25] that advanced periodontal disease (EOP) was confined to few sites in younger age groups, whereas the disease had a more generalized character in older subjects.

A possible explanation for the significantly smaller mean RABL in those over 60 years of age may be partly due to a higher frequency of guarded teeth, where the teeth with the greatest mean RABL were already extracted. Another possible explanation might be the small sample size of the over 60 years age group. Greater tooth mortality in this age group might also explain why there was less alveolar bone loss.

Regarding the rate of tooth mortality, the teeth most frequently missing were mandibular first molars (31.5%), maxillary first molars (24.2%) and mandibu-

Table 3. Distribution and prevalence of teeth mortality of the EOP and the AP in the maxillary arch by age group

Tooth location	Teeth Loss EOP age < 31 n/24* (%)	AP age 31–40 n/164 (%)	AP age 41–50 n/82 (%)	AP age 51–60 n/54 (%)	AP age > 60 n/32 (%)
17 & 27	1 (4.2)	8 (4.9)	17 (20.7)	21 (38.9)	13 (40.6)
16 & 26	2 (8.3)	27 (16.5)	21 (25.6)	17 (31.5)	19 (59.4)
15 & 25	1 (4.2)	18 (11.0)	9 (11.0)	8 (14.8)	10 (31.3)
14 & 24	2 (8.3)	13 (7.9)	8 (9.8)	5 (9.3)	7 (21.9)
13 & 23	1 (4.2)	7 (4.3)	3 (3.7)	3 (5.6)	3 (9.4)
12 & 22	1 (4.2)	22 (13.4)	4 (4.9)	7 (13.0)	4 (12.5)
11 & 21	2 (8.3)	24 (14.6)	9 (11.0)	8 (14.8)	4 (12.5)

n = number of teeth lost; *number of teeth examined.

Table 4. Distribution and prevalence of teeth mortality of the EOP and the AP in the mandibular arch by age group

Tooth location	Teeth loss				
	EOP age < 31 n/24* (%)	AP age 31–40 n/164 (%)	AP age 41–50 n/82 (%)	AP age 51–60 n/54 (%)	AP age > 60 n/32 (%)
37 & 47	0 (0)	34 (20.7)	13 (15.9)	25 (46.2)	10 (31.3)
36 & 46	2 (8.3)	56 (34.1)	27 (32.9)	21 (38.9)	6 (18.8)
35 & 45	1 (4.2)	16 (9.8)	10 (12.2)	15 (27.8)	5 (15.6)
34 & 44	1 (4.2)	8 (4.9)	8 (9.8)	11 (20.4)	9 (28.1)
33 & 43	0 (0)	3 (1.8)	3 (3.7)	3 (5.6)	3 (9.4)
32 & 42	2 (8.2)	15 (9.2)	10 (12.2)	7 (13.0)	5 (15.5)
31 & 41	5 (20.8)	21 (12.8)	19 (23.2)	13 (24.1)	6 (18.8)

n = number of teeth lost; *number of teeth examined.

lar second molars (23.0%). Results also revealed that tooth mortality was lowest for canines compared to other teeth. These results are in general agreement with those reported by Becker et al [26] and Rohner et al [14].

Tooth mortality by age group showed a gradually increasing tooth loss rate with increasing age for any maxillary tooth. Similar tooth mortality by age was found for mandibular teeth, but the highest tooth loss occurred at second (46.2%) and first (38.9%) molars in the 51–60-year age group, instead of the over 60 years age group. This indicates that the majority of tooth loss of periodontal origin occurred in mandibular molars and central incisors during the fifth decade of life (51–60 years of age group). This finding is in agreement with the report by Becker et al [26]. A possible explanation for the higher tooth loss rate of mandibular molars in the 51–60 years age group than in maxillary molars at age over 60 years may be that mandibular molars with two roots had less resistance to tooth loss than did maxillary molars with three roots, given similar means of RABL. The teeth lost to individuals due to nonperiodontal causes were excluded from the study. Thus, our study seems likely to reflect tooth mortality associated with periodontitis. This also indicates that periodontitis is the most important cause of early tooth loss. Our results are in agreement with other reports that concluded that the rate of periodontal destruction reaches a peak at about 51–60 years of age, and thereafter, decreases [27, 28].

The present study also documented that tooth mortality rate tended to decrease with decreasing mean RABL for any tooth type and in either arch. The highest tooth mortality rate being associated with a sudden decrease in mean RABL in the over 60 years age group strongly indicates that AP seems to be the most important cause of tooth loss and mean RABL in our study. This conclusion is generally in accordance with recent reports by other investigators [18, 19, 29, 30] that the higher the tooth loss, the greater the mean RABL, when the mean RABL of missing teeth was included in the sample pool.

Although, it is well known that radiographic methods are not accurate for measurements of interproximal RABL, the reliability, validity and relative specificity have been shown to be of essential importance. In particular, the combined use of the standardized paralleling radiographic technique with Eggen film holders [31] to assess the clinical measurements of the alveolar bone is useful in either cross-sectional epidemiologic or longitudinal follow-up surveys [19, 29, 30, 32]. Salonen et al maintains that it is possible to control the reproducibility of the diagnostic interpretation over time for longitudinal follow-up surveys [19]. Variations in beam projection that result in the foreshortening or elongation of radiographic images can be effectively minimized by using the percentage of the ratio of interproximal RABL to the root length or tooth length, measured on the periapical radiograph [19, 29, 31, 33]. In addition, the relatively constant relationship between tooth and root length has also been documented [19].

We found that alveolar bone defects generally increased with age, which is in agreement with others [18, 34]. Mean RABL peaked at 51–60 years of age. This finding is also consistent with most other investigators [28, 29].

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早期發作與成年牙周炎牙周骨破壞量的研究

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本研究目的是，應用數位掃瞄 X 光影像分析法評估國人未治療之早期發作性牙周炎及成年牙周炎之牙周骨破壞量。取材自過去 20 年被診斷的早期發作性與成人性牙周炎的 178 位患者，包括 96 位男性與 82 位女性，牙齒總數 4,262 顆。檢查、計算早期發作性與成人性牙周炎牙周骨破壞量。研究材料與方法包括標準牙根尖 X 光片、掃瞄器、電腦程式系統及 Microstation 95 影像軟體。結果如下：(1)早發性牙周炎上、下顎前牙區的 X 光牙周齒槽骨破壞量明顯大於慢性牙周炎；(2)早發性牙周炎齒槽骨最大破壞量，最常發生在第一大臼齒與下顎門牙區；而成人性牙周炎的最大破壞量最常發生在第一及第二大臼齒；(3)牙周齒槽骨破壞量的大小依序分別為大臼齒、門牙、小臼齒、犬齒　；(4)早發性牙周炎與成人性牙周炎齒槽骨破壞量隨年齡增加而增加；(5)早發性牙周炎牙齒喪失率最常發生在第一大臼齒及正中門齒及下顎門齒與第一大臼齒，成人性牙周炎牙齒喪失率最常發生在上顎第一及第二大臼齒及下顎第二大臼齒與正中門齒。結論顯示，未治療過的早發性牙周炎的牙周齒槽骨破壞量與破壞速度明顯比成人性牙周炎患者大而且快。

關鍵詞：數位影像分析；牙周齒槽骨；早發性牙周炎；成人性牙周炎

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