Assessment of the changes in alveolar bone quality after fixed orthodontic therapy: A trabecular structure analysis

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Abstract

Background. Tooth displacement changes the periodontium. The aim of orthodontic treatment is desired tooth movement with minimum side effects on the alveolar bone quality. The aim of the present study was to assess changes of alveolar trabeculation in children, young adults and adults and the two genders.

Methods. In this cross-sectional study, 63 patients who had been treated in Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran, were chosen with convenient sampling method. They were divided into three groups based on their age. Their digitized panoramic radiographs (PRs) were evaluated at six interdental sites from the mesial aspect of the mandibular second molars to the distal aspect of the mandibular first premolars using a visual index. The trabeculation pattern was assigned as either dense (score 3), dense-sparse (score 2) or sparse (score 1). Data were imported to SPSS. Mean of the scores before treatment (score B) and mean of them after treatment (score A) were compared for each group with paired t-test. Changes between score B and score A of the groups were compared using one-way ANOVA and post hoc tests.

Results. Mean score A was significantly higher than mean score B in children (P = 0.001). In contrast, mean score A was significantly lower than mean score B in young adults (P = 0.003).

Conclusion. Orthodontists should be cautious when treating young adults and adults regarding the probable, yet possibly temporary, negative effects of orthodontic therapy on the alveolar bone quality.

Key words: Bone, orthodontic appliances, panoramic radiography.

Introduction

The term “bone quality” has been used to refer to different bone characteristics, including bone trabeculation.1-4 To predict the bone strength, both trabecular density and trabecular microstructure are important since high density of bone does not necessarily mean high trabecular variables such as trabecular thickness and number.5,6 Also the risk is higher in patients with sparse alveolar trabecular pattern.7-9 The structure of the trabecular bone is critical for the stability of an endosseous implant and mini-
implant. Trabecular bone structure can be evaluated
using different approaches. Methods of fractal di-

dimension analysis and visual observation can be used
on two-dimensional plain radiographs whereas a
special imaging software is used in three-
dimensional (3D) imaging modalities. The com-
plexity and high cost of the 3D methods limit their
application for everyday use. However, the inexpen-
sive panoramic radiographs (PRs) and intraoral
views provide information about the maxillary and
mandibular bone without undue exposure.

An increase in population knowledge and their
esthetic demands leads to more orthodontic treatments
among different age groups. The aim of orthodontic
treatment is to move the teeth with minimum side
effects on the alveolar bone quality. Tooth dis-
placement necessarily changes the gingiva, peri-
dontal fibers and alveolar bone. Orthodontic
tooth movement is believed to happen either
“through bone” or “with bone”. When teeth are di-
placed “with bone”, the amount of the alveolar bone
resorption in the direction of the force balances the
bone apposition, with no net loss of bone. Howev-
er, hyalinization occurs and resorption begins if the
pressure is too high on the periodontal ligament
(PDL). Hyalinization results in the tooth movement
“through bone”. Besides, the balance between appo-
sition and resorption is disturbed, leading to a net
loss of bone. Orthodontic therapy is a combina-
tion of these two types of tooth movements. Therefore,
it can affect alveolar bone quality.

A few studies have been conducted to evaluate the
effect of orthodontic treatment on bone quality. In the
studies, density or thickness of cortical bone
has been used as a measure of bone quality. Huange
et al evaluated the density of one interdental area,
between the left first molar and the second premolar
in the maxilla and mandible, while Hsu et al assessed
the density of maxillary anterior segment. In both researches, the alveolar bone density was found
to decrease after orthodontic treatment. However,
Patil et al declared that alveolar bone density would
increase after orthodontic treatment.

It is well known that patients’ gender, race and age
can influence the bone metabolism. To the best of
our knowledge, none of the previous studies con-
sidered the patients’ age and gender in orthodontic
patients. Moreover, changes of trabecular structure
after orthodontic treatment have not been evaluated
previously. Therefore, this study was aimed to assess
alterations in the quality of alveolar bone in mandi-
bular posterior segment after fixed orthodontic

treatment by evaluating the changes in trabecular

structure in male and female subjects in different age
groups.

Methods

The research protocol of this study was approved by
Ethics Committee of Shiraz University of Medical
Sciences (Grant #92-01-21-6843). The patients’ data
were kept confidential.

In this analytical cross-sectional study, 63 orthodontic
patients, who had been referred to Department of
Orthodontics, School of Dentistry, Shiraz University
of Medical Sciences, were selected with conven-
tient sampling method. They were all treated by one
clinician and a similar appliance system [0.022 in,
MBT prescription, Mini Master Series™ American
Orthodontics™ metal brackets (Sheboygan, WI,
USA)] was used. Similar materials and strategies
were used in all the subjects: type of archwire [Nick-
el Titanium (NiTi) (3M Unitek, Monrovia, Califor-
nia, USA), stainless steel (SS) (3M Unitek, Monro-
via, California, USA)], elastomeric ligature (Ameri-
can Orthodontics, Sheboygan, WI, USA), elastomeric
chains, elastics, separators and rotational wedges
(G & H Orthodontics, Franklin, USA). The inclu-
sion criteria consisted of available PRs both before
and after fixed orthodontic treatment, which were
diagnostically acceptable after digitization and taken
at the same center and by the same machine (Plan
MecaPromax, Plan Meca, Helsinki, Finland); non-

extraction treatment regardless of third molars; prop-
er oral hygiene (plaque index<10 %); generalized
moderate crowding (4–7 mm); treatment by one clini-
cian with the same treatment mechanics (arch ex-
pansion); similar treatment duration (1.5 years ± 6
months). Exclusion criteria consisted of patients with
a history of orthognathic surgery; any systemic di-

ease affecting bone; taking drugs with effects on
bone metabolism during the treatment period; any

grade of periodontal disease and alveolar bone loss
before initiation of treatment; any impacted tooth;
any visible anomalies and pathologic lesions of the
mandible in PRs.

The patients were assigned to three age groups
based on World Health Organization classification
defined as below:

Group 1: children: 0–14 years of age
Group 2: young adults: 15–24 years of age
Group 3: adults: ≥25 years of age

The PRs before and after treatment were digitized,
in grayscale mode, at 600 dpi using a flatbed scanner
(Epson Expression 1600 Pro, Seiko Epson Corp.,
Japan). Digitization was performed to allow for im-
age adjustments so that all the radiographs could be
examined in a comparable status of contrast and light
intensity. A lossless format of Tag Image File For-
mat (TIFF) was used to save the radiographs in a
storage device. The images were assessed with Im-
age software which allows correction of both the
contrast and the intensity of light (Adobe Photoshop
7.0, Adobe Systems Corporation Inc, San Jose, Cali-
ifornia, USA).

The following visual assay was used to evaluate
the trabeculation of the alveolar bone (Figure 1):26

Score 1: Sparse: Bone marrow spaces are large,
especially in cervical regions.

Score 2: Dense-Sparse: In cervical regions, the tra-
beculation is denser and it is sparser apically.

Score 3: Dense: Bone marrow spaces are small
even under the roots and the whole region has equal
degree of trabeculation.

The evaluation was conducted on six interdental
sites bilaterally, from the mesial side of the mandibu-
lar second molars to the distal side of the mandibular
first premolars. The assessed areas were surrounded
by lamina dura of the adjacent roots mesiodistally;
they included the alveolar crest to 3 mm apical to the
roots cervicoapically. All the PRs were mixed before
and randomly to blind the examination. One expe-
rienced oral and maxillofacial radiologist carried out
all the assessments of alveolar bone trabeculation.

If accurate evaluation of interdental sites was hin-
dered by root proximity, idiopathic osteosclerosis,
mandibular tori superimposition or any other ana-
tomic structures, this interdental region was not in-
cluded in the examination. Whenever trabeculation
pattern was difficult to put into the defined scores, it
was considered in score 2.

Statistical analysis

Consequently, for each patient there were six num-
bers for trabeculation before orthodontic treatment
and six numbers after the treatment. Data were im-
ported into SPSS software (SPSS Software, Version
13.0; LEAD Technologies, Inc., Chicago, IL). Mean
of the scores before treatment (score B) and after
treatment (score A) were compared for each age
group using paired t-test. Furthermore, changes be-
tween the mean score B and the mean score A of the
three age groups and the two genders were compared
with one-way ANOVA and post hoc tests.

Since a visual scale was used to evaluate panoram-
ic radiographs, all the images were assessed once
again after 60 days by the same radiologist to ex-
amine the intra-operator errors. Kappa statistic (K-
value) was used to estimate the correlation between
the two sets of the reported scores and evaluate the
intra-examiner reliability.

Results

The total number of patients was 63 (42 females and
21 males). There were 33 patients consisting of 20
females and 13 males in group 1. There were twenty
patients in group 2, including 16 females and 4
males. In group 3, there were ten patients: 6 females
and 4 males.

K-value for the reported scores of the two evalu-
a tions was 0.91, indicating excellent intra-examiner
reliability. The scores of the first assessment were
applied in the statistical analysis.

It was shown that mean score A was significantly
higher than mean score B in group 1 (P = 0.001). In
contrast, mean score A was significantly lower than
mean score B in group 2 (P = 0.003). The difference
between mean scores A and B was not statistically
significant in group 3 (P = 0.587; Table 1).

ANOVA and post hoc tests showed mean differ-
ence of trabeculation score for group 1 was signif i-
cantly higher than groups 2 and 3 (P = 0.001, 0.029
respectively), but there was no statistically signif i-
cant difference in mean changes of trabeculation pat-
tern before and after treatment between groups 2 and
3 (P = 0.846; Table 2).

Figure 1. The three-scale visual analysis for assessment of bone trabeculation. A = Sparse, B = Dense-Sparse, C =
Dense. Image extracted from “Pham D, Kiliaridis S. Evaluation of changes in trabecular alveolar bone during
growth using conventional panoramic radiographs. Acta Odontologica Scandinavica. 2012;70:129”, reprinted by
permission of Taylor & Francis Ltd, www.tandfonline.com on behalf of Acta Odontologica Scandinavica Society.
v1.9 (license # 3966071191260).
Males and females also showed no statistically significant difference in the mean changes of trabeculation pattern before and after treatment (P = 0.966).

Discussion

The present study assessed changes in the alveolar bone quality in the mandibular posterior segment after fixed orthodontic treatment by evaluating changes in trabecular pattern in male and female subjects in different age groups.

K-value of 0.91 indicates almost perfect intra-examiner reliability. This means that the first visual evaluation of radiographs was reliable for interpretation and therefore we safely used the scores of the first assessment in statistical analyses.

Changes in the pattern of bone trabeculation and bone density are affected by several local and systemic variables. Attempts were made to eliminate the effect of these confounding factors by using strictly set inclusion and exclusion criteria for the study. The role of growth in bone changes during orthodontic treatment can be considered minimum during a treatment period of 1.5 years ± 6 months according to inclusion criteria. But patients’ gender, race and age can influence bone metabolism. Kiliaridis et al. conducted a research to evaluate changes in alveolar bone trabeculation during growth using the same three-scale visual analysis on PRs taken two and ten years following orthodontic treatment and to discover possible differences in patterns of trabeculation in patients of various genders and ages. They found that denser trabeculation in the alveolar bone seemed to be related to age. Although they reported a slight increase in bone trabeculation after eight years in both young and adult groups, it was not statistically significant. They suggested that eight years was a short time to evaluate changes induced by the growth process. Also, in the adult group, a more significant change was found during the eight-year longitudinal assessment.

As stated earlier, the structure of trabecular bone can be evaluated by different methods: analysis of fractal dimension, visual observation and specific imaging software programs. Fractal dimension analysis and visual observation can be used on two-dimensional plain radiographs whereas a special imaging software is used in 3D imaging techniques. A three-scale visual analysis was applied in our study, which has been shown to evaluate trabeculation on PRs in previous studies. It has already been proved that PRs can be as useful as periapical radiographs in assessing trabecular pattern. Although CBCT and other advanced 3D modalities of radiography are more accurate and provide more details, taking them routinely for orthodontic purposes seems unnecessary and uncommon because of their cost and lack of availability in all the oral and maxillofacial radiology centers and also their significant radiation doses.

Based on our results, trabecular structure of mandibular interdental areas became denser in children after fixed orthodontic treatment. In contrast, the trabeculation became sparser in young adults after treatment. Changes in trabeculation in young adults were more prominent than in children. In adults, although a slight reduction in alveolar trabeculation took place, it was not statistically significant. Therefore, considering the trabecular structure, it could be said that the alveolar bone quality of mandibular posterior segment might increase, decrease or remain unchanged after fixed orthodontic treatment in different age groups. Therefore orthodontists should be cautious when treating young adults and adults, especially in those who already have background osseous problems. Orthodontic therapy might predispose these individuals to decreased bone quality and the associated consequences such as a greater risk of fracture and instability of endosseous implants in future. As an example, a delay is suggested after completion of fixed orthodontic therapy for the placement of endosseous implants.

A few studies have been conducted to evaluate the

### Table 1. Mean difference in trabeculation score of alveolar bone before and after treatment in different age groups

| Age group | (Score A)-(Score B) | Number of patients | P-value |
|-----------|---------------------|-------------------|---------|
| Children  | +0.18686            | 33                | 0.001   |
| Young adult | −0.26668          | 20                | 0.003   |
| Adult     | −0.18336            | 10                | 0.587   |

Score A: Mean of trabeculation score after treatment; Score B: Mean of trabeculation score before treatment.

### Table 2. Comparison of mean difference of trabeculation score of alveolar bone before and after treatment between different age groups

| Groups | Children (P-value) | Young adult (P-value) | Adult (P-value) |
|--------|-------------------|----------------------|-----------------|
| Children | —                 | 0.45354 (0.001)     | 0.37022 (0.029) |
| Young adult | −0.45354 (0.001) | —                   | −0.08332 (0.846) |
| Adult    | −0.37022 (0.029)  | 0.08332 (0.846)     | —               |
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Dental Surgery.

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Effect of orthodontic treatments on bone quality. In most of the previous studies, bone density was used as a measure of bone quality. Huange et al. used CBCT-based degree of bone mineralization (DBM) to evaluate alterations of bone density distribution in the maxilla and mandible after orthodontic treatment in 43 patients ranging from 11.5 to 17.4 years of age. Although they did not aim at discovering whether the alveolar bone density would decrease or increase, they showed that the computed tomography (CT) attenuation parameters increased (without any statistical analysis or mentioned P-values), which means that the alveolar bone density and subsequently bone quality increased. This is consistent with our results in children. Although, no strict inclusion and exclusion criteria were set in the study of Huange et al., we considered several factors such as malocclusion type, oral hygiene, crowding, and treatment mechanics, etc, none of which being considered in sample selection in a research conducted by Huange et al.

Hsu et al. assessed changes of bone density around maxillary anterior teeth during orthodontic therapy on CBCT images. The alveolar bone was also divided into three regions of cervical, middle and apical and the amount of bone density changes in these three regions was compared. The density of alveolar bone reduced significantly with a mean of 24% after seven months of application of orthodontic forces but did not differ significantly between the aforementioned regions. Sample volume was eight patients, which is very small. They were only 20–25 years of age. In this study, the mandible was evaluated and similar results about bone quality were obtained in our research for the young adults. In the study by Hsu et al., the effects of gender and age were not considered and detailed inclusion and exclusion criteria were not applied.

Patil et al. evaluated alterations in density of bone using digital subtraction radiography at the crestal and subcrestal regions of interproximal alveolar bone of maxillary and mandibular posterior teeth before and after orthodontic therapy on digital PRs. The sample volume was 14 with an age range of 13–18 years. Unlike other studies, alveolar bone quality improved in most regions (82.14%), with a significant increase in the density of bone. Similar results were found in our study in children. As in other studies, the investigation of Patil et al. did not consider the effect of gender and age.

In our study, in growth termination group, the number of cases seemed to be insufficient (10 patients), which led to insignificant differences in statistical analysis. Furthermore, as women seek orthodontic treatment more than men, gender distribution among different groups was not even and the number of females was twice as males. This may be the reason of the absence of statistical significant between genders in this study. Therefore, future studies with larger sample sizes might show differences between the two genders. By using digitization, conventional radiographs may lose some data. Thus, it is advised to use digital imaging rather than digitization of conventional panoramic radiographs in future studies. Also, we only assessed mandibular alveolar bone. Rather than visual analysis which is an operator-dependent method, more objective approaches such as fractal dimension analysis should be used to evaluate both maxillary and mandibular alveolar trabecular pattern to enhance the accuracy in future studies.

Conclusion

Alveolar bone quality might decrease, increase or remain unchanged after fixed orthodontic treatment in different ages. Within the limitations of the present study, it was concluded that orthodontists should be cautious when treating young adults and adults, especially those with background osseous problems, in whom orthodontic treatment might negatively affect alveolar bone quality and might at least temporarily predispose them to instability of endosseous implants or a greater risk of osseous fracture.

Authors’ contributions

The study was designed by AH and HZN, and M Sabet carried out the study procedures. The statistical analyses and explanation of data were carried out by M Sabet and M Saki. M Saki prepared the draft of manuscript. HZN and AH critically revised the manuscript. All the authors
contributed to the final draft, read and approved the final manuscript.

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**Competing interests**

The authors declare no competing interests with regards to the authorship and/or publication of this article.

**Ethics approval**

The research protocol of this study was approved by the Ethics Committee of Shiraz University of Medical Sciences (#92-01-21-6843).

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