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Change in mandibular incisor facial bone height and thickness following Class II correction with a compressed coil spring appliance

Daniel P. Chartrand and Brian W. Penton

Introduction

Perhaps not since the advent of the roentgenogram by Wilhelm Conrad Röntgen in 1895 has the innovation of a new technology held the potential to alter orthodontic perceptions and practice so much. Cone beam computed tomography (CBCT) is opening never available before perspectives into diagnosis, treatment planning, and evaluation of treatment results. In many cases what is being found by orthodontists on 3-dimensional cone beam images are surprising and unexpected, and in some cases those findings bring into question current beliefs about proper practice.

Dr. Charles Tweed based much of his diagnostic work and treatment goals on evaluations of a 2-dimensional lateral cephalometric radiograph and a point of central interest was the lower incisors relative to the mandibular plane. The key tenant that has been adhered to by orthodontists everywhere in the decades since has been that lower incisors must be upright over basal bone. Great discussion, mechanical effort, and appliance designs have occurred in efforts to prevent lower incisor proclination based on this fundamental convention.

The Tri-Service Orthodontic Residency Program (TORP) began taking CBCTs routinely on all new patients in 2014. It was determined at that time that the balance between radiation dose and potential diagnostic benefit shifted in favor of using CBCTs in this manner. In 2016, as those first orthodontic cases came to completion, numerous unexpected findings were encountered. One such finding came at the position of lower incisor roots relative to the alveolus and basal bone following Class II correction. In some cases where careful control of lower incisor proclination had been attempted it appeared that the roots had exited the alveolus anteriorly and were no longer over the skeletal body of the mandible (See Figure 1). The findings were significant and common enough to give rise to concern and were, in fact, the nidus for the research that follows.

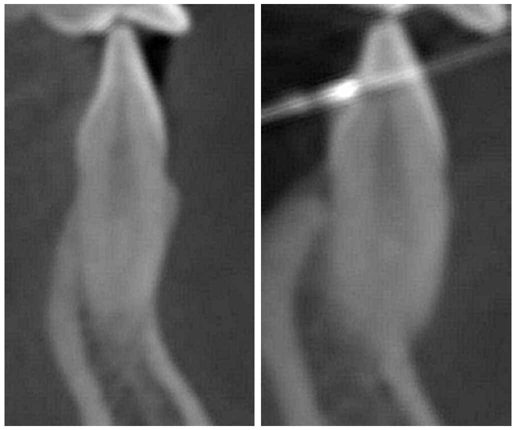

Figure 1. Before and after treatment cone beam slices of mandibular incisor with root apex apparently beyond the alveolar housing.

Historically, much attention has been given to buccal bone reduction of molars and premolars following rapid palatal expansion, yet, there is very little research studying the bone surrounding lower incisor following Class II correction. Schwartz et al[1]. studied the changes in alveolar bone support of lower incisors induced by the Herbst. The retrospective study concluded that CBCT scans showed an association between the Herbst appliance and alveolar bone loss on the buccal surface of mandibular incisors, however, without clinical significance[1]. Unfortunately, their study lacked a control group to compare these results to. To our knowledge no research has been conducted studying the effect of a compressed coil Class II corrector on alveolar bone in the mandibular incisors. Therefore, the purpose of this retrospective study was to evaluate the change in mandibular incisor bone height and facial thickness following non-extraction Class II correction with a compressed coil spring appliance compared to a control group of Class I patients treated with non-extraction comprehensive orthodontic therapy alone.

Materials and Methods

This retrospective study was comprised of 40 non-extraction orthodontic patients. The mean age was 15.10 years for the control group and 13.62 years for the test group. There were 25 females and 15 males. The control group consisted of 20 patients with Skeletal Class I malocclusion diagnosed by ANB $\geq 0.1^0$ and $\leq 3.1^0$. Inclusion criteria was: Class I molar and canine relationship, mild to moderate crowding and complete permanent dentition. Exclusion criteria was: ANB $<0.1^0$ or $>3.1^0$, severe crowding and missing teeth.

The test group consisted of 20 patients with skeletal Class II malocclusion treated with comprehensive orthodontic therapy and a compressed coil spring appliance. Skeletal Class II malocclusion was diagnosed by ANB $>3.1^0$. Inclusion criteria was: convex facial profile, Class II molar and canine relationship, mild to moderate crowding and complete permanent dentition. Exclusion criteria was: ANB $\leq 3.1^0$, severe crowding or missing teeth. Twin brackets and self-ligating brackets with the MBT prescription including -6^0 torque for the mandibular incisors were used. One patient from the control group was treated with clear aligner therapy. All Class II patients were treated with a compressed coil Class II corrector until an end-to-end incisor relationship was achieved. The compressed coil spring Class II correctors were either the Forsus (3M Unitek, St. Paul, MN, USA) or the Power Scope (American Orthodontics, Sheboygan, WI, USA).

The I-CAT Next Generation (Imaging Sciences, Hatfield, PA, USA) was used to obtain large volume 3-dimenesional scans (17cm x 23cm, 0.3mm Voxel size) before treatment (T_0) and after treatment (T_1). Dolphin imaging software (Dolphin Imaging & Management Solutions, Chatsworth, CA, U.S.A.) was used to reconstruct a 2D lateral cephalogram and create sagittal slices to measure bone height and axial slices to measure bone thickness. The reconstructed lateral cephalograms were also used to compare SNA, SNB, ANB, Wits

(Functional Occlusal Plane), incisor mandibular plane angle (IMPA: Menton-Constructed Gonion) and L1-NB measurements before and after treatment.

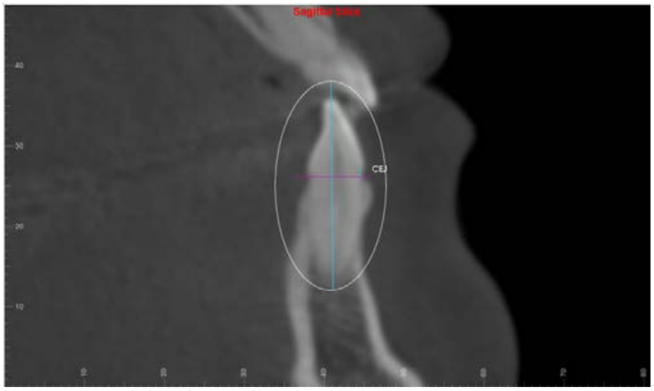

Figure 2. Sagittal slice showing bone height measurement.

Bone height was measured by taking sagittal slices at the center of the root of teeth #23, 24, 25 and 26. Measurements were made from the cementoenamel junction (CEJ) to the most superior part of the alveolar crest (See Figure 2). Bone height measurements were recorded as bone height (BH) for each tooth.

Buccal bone thickness of teeth #23, 24, 25 and 26 was measured by evaluating axial slices at 3, 6, and 9mm apical to the CEJ (See Figure 3). Measurements were recorded as bone thickness 1 (BT1), bone thickness 2 (BT2) and bone thickness 3 (BT3) for each respective tooth. Buccal bone thickness was defined as the measurement from the facial root surface to the buccal margin of bone.

A Mann-Whitney U test was used to compare the change in measurements (T_1-T_0) between the control group and the test group. Measurements for 10 randomly selected patients were repeated after two weeks by the same examiner. An Intraclass Correlation Coefficient (ICC) was used to compare the two sets of measurements and evaluate the reliability of the rater.

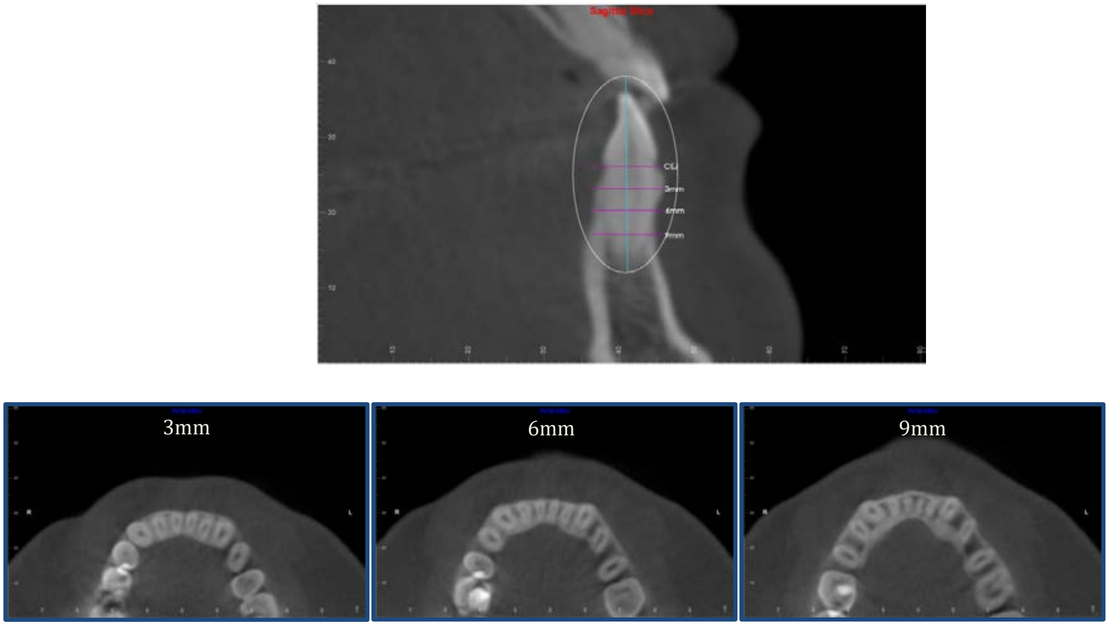

Figure 3. Axial slices at 3mm, 6mm and 9mm.

Results

A Mann-Whitney U test was chosen due to the nonparametric nature of the data collected and showed a statistically significant difference between the control group and the test group for buccal bone height for all four incisors and facial bone thickness at 3mm for tooth #24 (P-value= 0.03) and #26 (P-value= 0.01). There was also a statistical significance for change in SNB, ANB, WITS and IMPA between the control group and the test group.

Overall, the bone height decreased by an average of 1.67mm for the control group and 3.04 mm for the test group (See Table 1 and 2). There was an average of 1.37mm more bone height reduction in the test group than in the control group. This change in bone height for the control group is similar to that found by Garlock et al[2].

	Bone Height (mm)				
	Tooth	**23**	**24**	**25**	**26**
Control	T_0	2.99	3.03	3.31	2.64
	T_1	4.68	4.57	5.05	4.34
	Δ T_0-T_1	**-1.70**	**-1.55**	**-1.74**	**-1.70**
Test	T_0	2.96	2.93	2.89	2.61
	T_1	5.83	5.73	5.96	5.80
	Δ T_0-T_1	**-2.88***	**-2.8***	**-3.07***	**-3.19***

Table 1. Mean distance from CEJ to alveolar crest for each mandibular incisor at T_0 and T_1.; *Indicates statistically significant.

	Mean Bone Height (mm)		
	T_0	T_1	ΔT_0-T_1
Control	2.99	4.66	-1.67
Test	2.82	5.86	-3.04

Table 2. Mean distance from the CEJ to alveolar crest for all 4 incisors from T_0 to T_1.

Tooth	p-value
BH23	0.02*
BH24	0.02*
BH25	0.05*
BH26	0.02*

Table 3. p-values for change in bone height. *indicates statistical significance

Bone thickness for the control group changed by an average of -0.06mm (at 3mm), -.01mm (at 6mm), and +0.24mm (at 9mm). Bone thickness for the test group changed by an average of -0.24mm (at 3mm), -0.22mm (at 6mm) and -0.68mm (at 9mm) (See Table 3 and 4).

		Bone Thickness (3mm)				Bone Thickness (6mm)				Bone Thickness (9mm)			
Tooth		**23**	**24**	**25**	**26**	**23**	**24**	**25**	**26**	**23**	**24**	**25**	**26**
Control	T_0	0.37	0.23	0.27	0.26	0.41	0.67	0.72	0.43	1.27	1.96	1.79	1.23
	T_1	0.22	0.24	0.20	0.27	0.41	0.91	0.65	0.31	1.48	2.41	2.07	1.23
	Δ T_1-T_0	**-0.15**	**0.01**	**-0.08**	**0.01**	**0.01**	**0.24**	**-0.06**	**-0.13**	**0.21**	**0.45**	**0.28**	**0.00**
Test	T_0	0.39	0.27	0.26	0.41	0.49	0.90	0.70	0.44	1.42	2.30	1.98	1.27
	T_1	0.11	0.06	0.07	0.11	0.33	0.61	0.45	0.26	1.48	2.23	2.04	1.14
	Δ T_1-T_0	**-0.28**	**-0.21***	**-0.19**	**-0.3***	**-0.17**	**-0.29**	**-0.26**	**-0.18**	**0.06**	**-0.07**	**0.06**	**-0.13**

Table 4. Mean bone thickness for each mandibular incisor at T_0 and T_1; *Indicates statistically significant.

	Mean Bone Thickness (mm Apical to CEJ)								
	T_0 (3mm)	T_1 (3mm)	ΔT_1-T_0	T_0 (6mm)	T_1 (6mm)	ΔT_1-T_0	T_0 (9mm)	T_1 (9mm)	ΔT_1-T_0
Control	0.28	0.23	**-0.05**	0.56	0.57	**0.01**	1.56	1.8	**0.24**
Test	0.33	0.09	**-0.24**	0.63	0.41	**-0.22**	1.74	1.72	**-0.02**

Table 5. Mean bone thickness for all 4 incisors at T_0 and T_1.

	3mm				**6mm**				**9mm**			
Tooth	**23**	**24**	**25**	**26**	**23**	**24**	**25**	**26**	**23**	**24**	**25**	**26**
p-value	0.25	0.03	0.26	0.01	0.19	0.06	0.44	0.23	0.42	0.34	0.62	0.44

Table 6. p-values for change in bone thickness.

The means for SNA, SNB, ANB, WITs, L1-NB and IMPA are shown in Table 5. IMPA for the control group increased by 4.19^0. The average increase in IMPA for the test group was $8.41^0 \pm 5.30^0$, which is consistent with previous authors[3]. Furthermore, the test group showed 0.6mm (2.06mm vs 1.46mm) increase in L1-NB relative to the control group, demonstrating a greater amount of protrusion of the lower incisors. ANB increased by 0.10^0 for the control group and decreased by 0.88^0 for the test group. The ICC was 0.944.

		SNA(^{0})	SNB (^{0})	ANB (^{0})	WITS (mm)	L1-NB (mm)	IMPA (^{0})
Control	T_0	82.77	80.87	1.90	-1.29	3.71	90.22
	T_1	82.45	80.41	2.00	-2.01	5.17	94.41
	ΔT_1-T_0	**-0.32**	**-0.46***	**0.10***	**-0.72***	**1.46**	**4.19***
Test	T_0	83.90	78.30	5.61	2.36	4.85	93.94
	T_1	83.61	78.90	4.73	0.09	6.91	102.35
	ΔT_1-T_0	**-0.29**	**0.60***	**-0.88***	**-2.27***	**2.06**	**8.41***

Table 5. Mean cephalometric measurements at T_0 and T_1; *indicates statistical significance.

	p-value
SNA	0.955
SNB	0.015*
ANB	0.001*
WITS	0.013*
L1-NB	0.255
IMPA	0.021*

Table 6. p-values for change from T_0-T_1 in control group vs test group. *Indicates significance.

Discussion

This retrospective CBCT study evaluated alveolar bone changes around mandibular incisors induced by a compressed coil Class II corrector. Traditionally, cephalographic radiographs have been used to evaluate incisor angulation. These two dimensional radiographs superimpose numerous structures in the mandibular incisor region making it difficult to accurately ascertain the relationship of the tooth root and supporting bone. The use of CBCT as a diagnostic tool has greatly increased in the field of dentistry. Dental CBCT is now regarded as the most reliable tool to reveal tooth and supporting tissue morphology in three dimensions. Winter et al[4]. suggested that this new technology has become the standard of care in diagnosing and treating problems in craniofacial growth and analyzing the mixed dentition. It allows for accurate display of the vertical as well as the buccal-lingual dimensions of the mandible. With the rise of CBCT use in orthodontic treatment planning, we are better able to visualize the relationship of the tooth within the alveolar housing and its relation to supporting skeletal bone. This will allow for better treatment planning for our patients in the future. As the pendulum swings towards non-extraction treatment and expansive orthodontics, three-dimensional imaging allows us to assess whether or not we are violating the limits of the supporting hard tissues and increasing the potential for iatrogenic damage. According to this study, use of a compressed coil Class II corrector resulted in significant buccal bone height loss in the mandibular incisors as well as buccal bone thickness reduction for tooth #24 and #26. Additionally, IMPA for the test group increased by twice as much as the control group (8.41^{0} vs 4.19^{0}). This increased tipping, which is common with Class II correctors, may offer an explanation as to the associated increased reduction in buccal bone height. As the coronal portion of the tooth is tipped facially, the already thin crestal bone is at greater risk of resorbing leading to a greater reduction in bone height. It is difficult to explain why the statistical significance in bone thickness was isolated to teeth #24 and #26. Because the reduction in bone thickness is such a small effect size, it is difficult to show a statistical significance with a sample size of 20 patients per group, however this reduction may have clinical implications in an area of already thin bone. In fact, the power analysis conducted prior to data collection indicated a sample size of 30 patients per group for a power of 80%. Unfortunately, we were only able to find 20 patients for the control group that met our inclusion criteria. Further studies with larger sample sizes are warranted.

Making small measurements using large volume CBCT scans has limitations. According to Molen[5], factors such as volumetric averaging, noise and artifacts make it difficult to achieve accurate measurements of thin bone, such as in the mandibular incisor region. The average width of the PDL is 0.25mm[6] and mandibular incisor facial bone may be just as thin. The voxel size used in this study was 0.3mm. This results in the high potential for volumetric averaging, making it difficult to distinguish the root surface and the surrounding bone. Additionally, volumetric averaging tends to underestimate the amount of bone that may actually be present[7,8,9]. Nevertheless, inaccuracies from volumetric averaging are accounted for in this study by including a control group. An ICC was also performed to test the rater's reliability in measuring areas of thin bone. Using a control group and a reliable rater allows us to draw conclusions that may not otherwise be possible. Molen[5] also suggests that radiographs made at the end of active treatment may not accurately depict the amount of bone present. He suggests waiting 12 months to allow for the newly formed woven bone to differentiate into a more radiopaque lamellar bone prior to making radiographs to be used for bone measurements. This study is not able to definitively say that there is no bone present on the facial surface following treatment. It does, however, show that there is a significant reduction in bone height for all incisors, and bone thickness for tooth #24 and 26.

Excess proclination of mandibular incisors is seen as unfavorable because it may increase the chance of a dehiscence, anatomically predisposing the patient to gingival recession. Gingival recession in the general population has been found to be more prevalent in mandibular teeth and on the facial surfaces[10]. Renkema et al. showed a positive association between recession and patients who underwent orthodontic therapy[11]. Unfortunately, all of the treated patients in their study also had bonded lingual retainers immediately after treatment, and the authors could not decipher if recession was due to orthodontic treatment or poor oral hygiene around the fixed retainer[11]. However, they also showed that excess proclination (mean IMPA=105.2^0) during orthodontic therapy did not result in more gingival recession when compared to a treated control group (mean IMPA=90.8^0) at a 5 year recall[10]. Photographic review at the end of treatment for this study revealed no apparent gingival recession for any patient. Therefore, according to this study Class II correction with a compressed coil spring appliance does not appear to negatively impact gingival tissue at the end of treatment. We must take care, however, to acknowledge that we do not fully understand the long-term implications of the bone reduction demonstrated in this study and how it relates to gingival stability. Nowarzi et al[12]. coincidentally showed, while studying facial bone thickness for treatment planning implant placement, that 12% of maxillary incisors presented with complete lack of facial bone with no apparent attachment loss. Such findings bring into question the relation between an absence of bony root coverage and gingival recession. Perhaps, as Chambrone suggests, the answer depends more on the periodontal phenotype than the underlying bone[13]. Until such time as these questions are answered, treatment within the "orthodontic walls"[14] will remain the most responsible way to ensure physiologic health and harmony. Careful evaluation of the mandibular incisor region to include both soft tissue and bone, is imperative when treating Class II malocclusions. Mandelaris et al[15]. have developed a classification system of dentoalveolar bone phenotypes, which may provide some guidance when evaluating suitability of supporting tissues during the treatment planning process.

Incidental finding

There were four patients with noticeably more bone loss than the rest of the control and test groups. One patient came from the test group and three patients were from the control group. All four incisors appear to be outside of the alveolar housing for these four patients (See Figure 4). Coincidentally, all four of these patients were treated with active self-ligating brackets. A possible explanation may be the interactive nature of the gate on these brackets resulting in full expression of the -6^0 torque and driving the root forward. The sample size is extremely small, and more studies need to be conducted to further evaluate these findings.

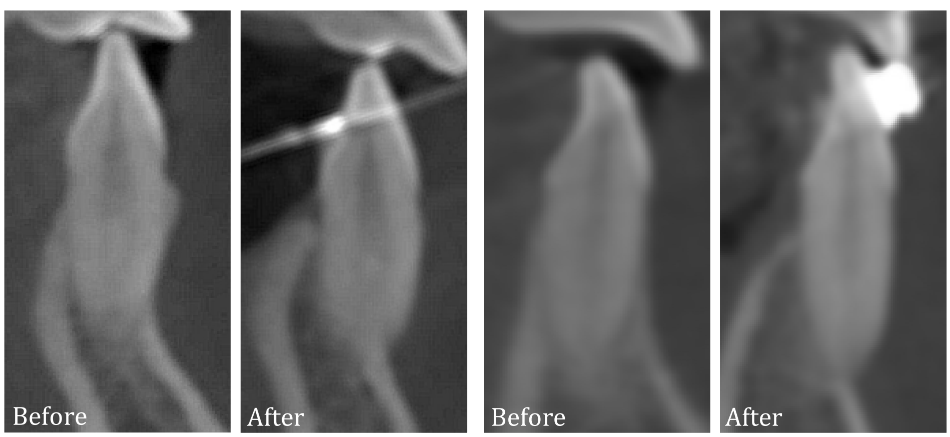

Figure 4. Images taken from 2 patients treated with active self-ligating brackets

Limitations

One limitation of this study was that it was a non-blinded retrospective study. This introduced potential bias and limited the ability to select for ideal candidates. The most reliable findings could be expected from a prospective study where patients with similar malocclusions were selected for the control group and the test group. Another improvement would come from having a blinded examiner evaluate the CBCTs to conduct the measurements. Furthermore, it would allow for control of treatment as far as which appliances were used and the duration of appliance therapy. This study used patients that were treated with a variety of appliances potentially leading to variables that could not be accounted for in this retrospective study.

Conclusion

Based on the results of this study, there is evidence to suggest that use of a compressed coil Class II corrector may be associated with decreased height and facial thickness of the supporting bone found adjacent to the mandibular incisors. Additionally, an incidental finding was that patients who underwent treatment with active self-ligating brackets appear to have more bone loss compared to both the control and test group. Further studies need to be conducted to provide more conclusive evidence for all outcomes. Additionally, according to the photographs reviewed during this study there was no apparent negative soft tissue impact using a compressed coil Class II corrector at the end of treatment, but studies including long term follow-up evaluations would be beneficial. A final recommendation for best clinical outcomes would be to identify hard and soft tissue borders and attempt to confine tooth movement within these borders.

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