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CORTICOTOMY-ASSISTED SLOW MAXILLARY EXPANSION WITH BONE ALLOGRAFT ASSESSED WITH CONE BEAM COMPUTED TOMOGRAPHY IN YOUNG ADULTS

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ABSTRACT

Introduction: There is low evidence regarding the effect of slow palatal expansion in the treatment of bilateral posterior cross-bite. In adults the treatment had always been directed to surgical maxillary expansion. Therefore, this study aimed at evaluating corticotomy-assisted slow palatal expansion using cone beam computed tomography (CBCT).

Subjects and Methods: The study included six females, 19-20 years old, with bilateral posterior cross-bite and Class III malocclusion. CBCT was taken pretreatment (T0), immediately post-expansion (T1) and three months following the end of orthodontic treatment (T2). Four banded quad-helix appliance assisted with buccal corticotomy and bone allograft was used for expansion. The expansion was activated every two months. Fixed orthodontic appliance was performed to continue the treatment of the cases. CBCT was used to measure and record amount of expansion and tipping of premolars and first molars. The bone fenestrations were also recorded as scores. Data were statistically analyzed.

Results: The bilateral posterior cross-bite was treated in 8.5 months. The amount of expansion increased significantly from T0-T1; 5.58±0.77mm, yet it was non-significant from T1-T2; 1.16±0.34mm. There was a significant increase in mean tipping angle from T0-T1 without a significant increase from T1-T2. Regarding buccal bone fenestrations, there was a significant increase from T1-T2 (1.59±1.19,1.79±1.18mm respectively). An inverse correlation was found between bone fenestration and cervical and middle buccal cortical bone thicknesses at T1 and T2.

Conclusions: Corticotomy-assisted expansion with quad-helix was an efficient treatment modality of bilateral posterior cross-bite in young adults. Moderate bone fenestration was recorded at the end of expansion.

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INTRODUCTION

The increased need for adult orthodontics, directed the research workers for more researches and modifications in this field. Bilateral posterior cross-bite presented about 1.6% of the female Egyptian population.[1] It is a malocclusion that had always been treated by surgically assisted rapid palatal expansion (SARPE) at the adult stage.[2] It was claimed that SARPE provided a more controlled tooth movement, that was well retained, with no periodontal side effects. But, as it is a surgical procedure, it has all side effects of surgeries and was also found to cause tipping of posterior teeth, bone dehiscence and relapse.[3-5]

The most recent systematic review concluded that slow maxillary expansion in adults needed more research work, and that clinical trials were so limited.[6-8] Accelerated osteogenic orthodontics (AOO), or periodontally accelerated osteogenic orthodontics (PAOO) was a modification of corticotomy, and was revised by Wilcko brothers from 2001-2008.[9] They claimed that it reduced the treatment time to one third of the conventional orthodontic time. It was beneficial in maxillary expansion, molar distalization, intrusion and orthodontic extrusion of impacted teeth. AOO increased the orthodontic tooth movement for at least two weeks post corticotomy, decreasing the risk of root resorption.[10-17] Thus, AOO technique could be a possible orthodontic intervention to treat bilateral posterior cross-bite at the adult age, as an alternative to SARPE.[18]

Cone beam computed tomography (CBCT), became an integral part of the diagnostic phase of cases that require orthodontic treatment, particularly non straightforward cases as well as being an effective post-operative evaluating tool for the treatment outcomes, especially in cases that need more than one stage of treatment. The increased usage of CBCT is attributed to its ability to provide massive amount of information in different planes with relatively low amount of radiation.[19-22]

SARPE was found to have significant decrease in buccal bone thickness when examined by cone beam computed tomography, on posterior teeth, but appeared to be clinically insignificant.[23,24] Thus, CBCT was proved to be a very important tool aiding in precision of diagnosing bone defects, hence used in our present study. The increased accuracy of measurements from CBCT comes from the sub-millimeteric isotropic voxel resolution, which ranges from 0.4 mm down to 0.075 mm with some systems. Computed tomography analysis of rapid maxillary expansion effects gave a better quantity and exactness of the diagnostic parameters measured, and might soon become the routine analysis for patients undergoing such treatment.[25-30]

Thus, the aim of the present study was to three-dimensionally evaluate the effect of slow maxillary expansion assisted with bone augmented corticotomy, in the treatment of bilateral posterior cross-bite in female adults. The bone dehiscence or fenestration would also be diagnosed and evaluated if present.

SUBJECTS AND METHODS:

This clinical trial has been registered in U.S. National Institutes of Health Clinical Trials Registry, Clinical Trials.gov Identifier: ***NCT02574117***.

Six female patients, age 19-20 years old with Angle class III malocclusion and bilateral posterior cross-bites were selected from outpatient clinic of orthodontic department, Faculty of Dentistry, Cairo University. They had 5-6 mm of crowding in the upper arch, with anterior cross bite, and minimal crowding in lower arch. They had no previous orthodontic treatment, nor any systemic disease that could affect bone density. Periodontal assessment revealed healthy gingiva with no pockets, nor bone resorption. The sample size calculation was based on study conducted by Chester S. Handelman, in 1997. A computed G power statistical program was used for sample size calculation using Wilcoxon signed-rank test. In this study, the response was normally distributed with standard deviation, 1.68. The total sample size was six, with probability power 0.95.

The type I error probability associated with this test of this null hypothesis is 0.05.[31]

The orthodontic records included; personal data, past medical and dental histories and study models. Cone beam computed tomograms, as well as, extra and intra-oral photographs were taken at three time intervals; pre-orthodontic treatment, post-expansion and three months after orthodontic treatment.

A) The orthodontic appliance:

The dental expansion was performed with 4-banded quad-helix appliance; at the first molars and premolars, using wire 0.9 mm which was contoured palatally to adapt to the palatal surface of the second premolars. **(figure 1)** The appliance was cemented and expanded half cusp unit on the early morning of corticotomy. At the end of expansion period, the quad-helix was removed and transpalatal arch was applied to retain arch expansion. The orthodontic brackets; Roth (0.022 x 0.025 inch slot) were bonded. The leveling and alignment wires were sequentially delivered, starting from 0.014 Niti and up to 0.019x0.025 inch stainless steel wires. The lower first premolars were extracted to correct the canine relation and anterior cross-bite.

B) Corticotomy with bone graft:

Patients found the proposed periodontal plastic surgical procedure with the incorporation of resorbable grafting material to be acceptable.

Fig. (1): Intra-oral photograph showing the quad helix appliance cemented in place.

The corticotomy technique used in this study is a modification of the basic corticotomy-facilitated orthodontics procedure described by Wilcko et al. (2009). Surgical procedures of corticotomy were performed on the buccal side of the maxillary arch on the right and left sides at the same appointment under local anesthesia. Using the William's graduated periodontal probe 4 mm were measured from the free gingival margin following contours of gingiva extending from mesial of maxillary 1st premolar to mesial of 2nd molar to demarcate the start of the horizontal incision. Surgical blade #15 was used to make a horizontal buccal incision leaving the gingival margin and interdental papillae intact.[12] This flap design was modified from the conventional design that utilizes intra sulcular incision, in attempt to eliminate risks of gingival recession. Full thickness muco-periosteal flaps were reflected labially from the mesial of maxillary 1st premolar to mesial of 2nd molar. The flaps were reflected beyond the root apices of the maxillary posterior teeth (Figure 2). Following flap reflection, selective alveolar decortication points were performed buccally on both sides in the form of alveolar perforations through the labial cortical plate of bone, using a small #2 round stainless steel surgical bur in low speed under copious irrigation. Numerous corticotomy perforations were made around the teeth extending from mesial of maxillary 1st premolar to distal of 1st molar (Figure 2a). Depth of holes was confirmed by bleeding from corticotomized bone. The corticotomy perforations extended just barely into the medullary bone.

An established augmentation procedure using bone allograft was then performed over the partially decorticated areas. Demineralized freeze-dried bone allografts (DFDBA) were used to take advantage of its potential inductive properties. (Figure 2b) Care was taken not to place an excessive amount of grafting material, as this might interfere with replacement of the flaps. Flaps were repositioned at their original pre-surgical site and sutured with non resorbable 4-0 black silk suture using single interrupted suturing technique. Post-operative care consisted of a prescription for a systemic antibiotic (Amoxicillin 500mg t.d.s), an anti-edematous drug (chymotrypsin t.d.s) and analgesic (Ibuprofen 600 mg t.d.s) for seven days. Patients were instructed to rinse twice daily for two minutes for a period of two weeks using 0.12% chlorhexidine gluconate.[5] The sutures were removed two weeks post-surgery.

C) Cone beam computed tomography (CBCT):

Cone beam computed tomography scans[6] were performed three times for each patient; at the beginning of the treatment (baseline) and at the end of expansion and orthodontic treatment (average 2.5 years after beginning of the treatment). The scans were performed with FOV 75×100 mm (H×D) and voxel size 0.3 mm, 85 kVp, 15 mA.

Measurements were taken on the first premolar, the second premolar, the first molar, and the second molar of the maxillary arch after standardization of the cuts in the three scans of each patient. They included; the change in the inter-arch distance between contra-lateral teeth at the level of maximum palatal contour of the crowns as indicator of amount of palatal expansion (figure 3) The change in the distance between buccal cusp tip of upper teeth in relation to the opposing teeth in the horizontal plane as an indicator for improvement of the cross bite, (figure 4). The change of the tipping angle (bucco-

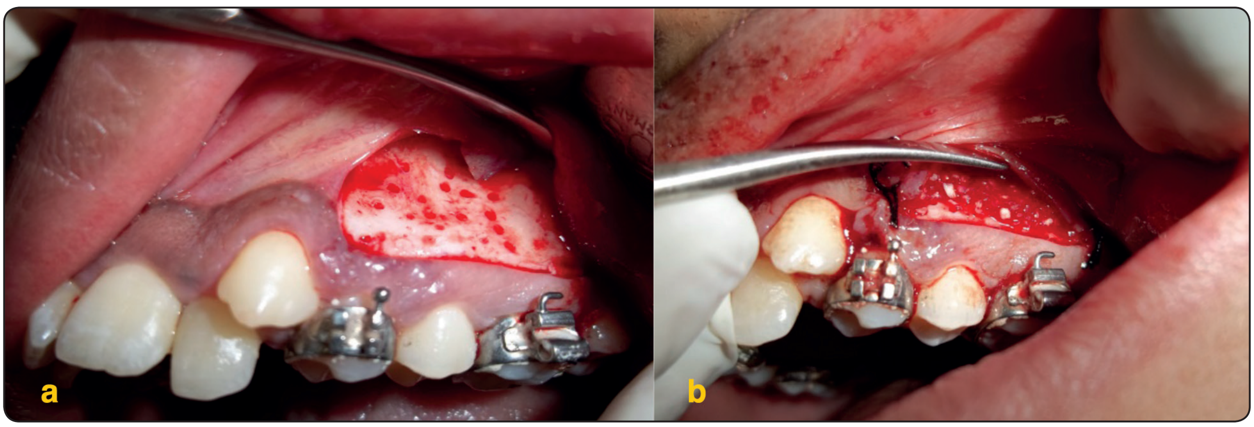

Fig. (2): Intra-oral photograph showing the flap reflected with corticotomy perforations (a) And followed by application of the bone graft; DFDBA (b).

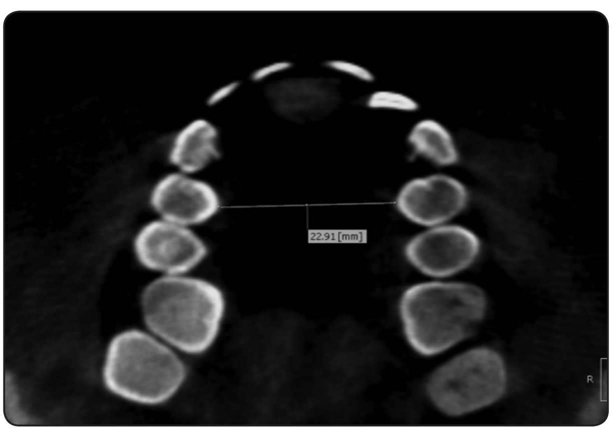

Fig. (3): Axial CBCT image showing measurement of intra-arch distance.

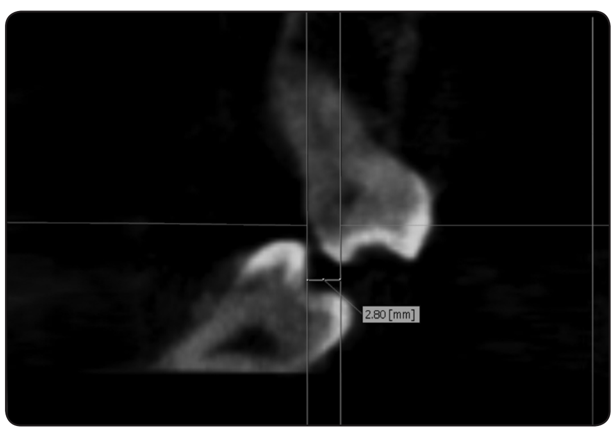

Fig. (4): Coronal CBCT image of measurement of cross-bite at first premolars.

palatally) of each tooth, (figure 5). The thickness of the buccal cortex at three levels; cervically, middle, and apically (figure 6), and finally the presence of buccal dehiscence with the following scoring: 0: No dehiscence, 1: cervical dehiscence, 2: cervical and middle dehiscence, 3: cervical, middle, and apical dehiscence (figure 7).

All measurements were performed by an oral and maxillo-facial radiologist with sixteen-year experience. The measurements were taken twice at two different sessions with two weeks interval in between. The means of the two measurements were pooled and included into further statistical analysis.

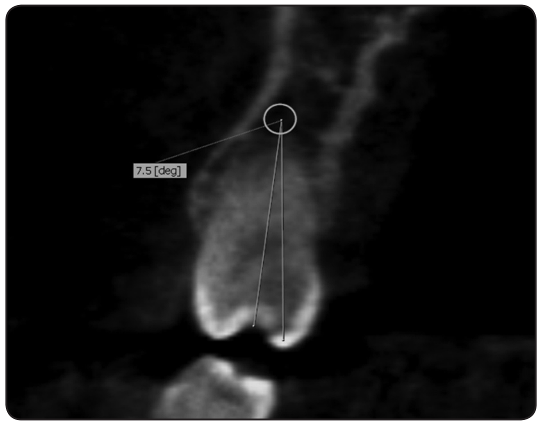

Fig. (5): Coronal CBCT image showing the measuring of tipping angle of the right second premolar.

Statistical analysis

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Intra-arch distance data showed parametric distribution, while change in tipping angle, cross bite, dehiscence and buccal cortex thickness data showed non-parametric distribution. Data were represented as mean, standard deviation (SD), median, range and 95% Confidence interval (95% CI) values.

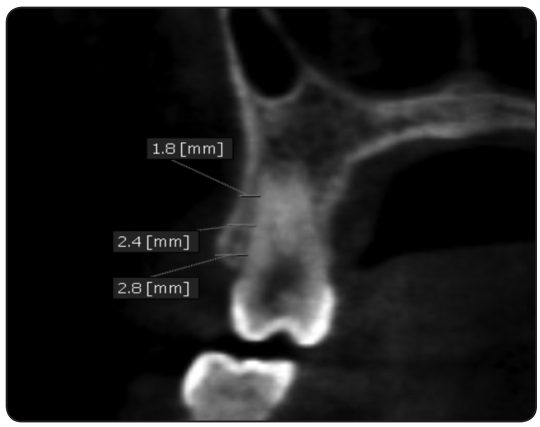

Fig. (6): Coronal CBCT image showing measuring the thickness of buccal bone for the right second premolar at cervical, middle, and apical thirds of the root.

For parametric data; for repeated measurements ANOVA test was used to study the changes by time. Tukey's post-hoc test was used for pair-wise comparisons when ANOVA test is significant.

For non-parametric data; Friedman's test was used to study the changes by time in tipping angle and cross bite. Wilcoxon signed-rank test with Bonferroni's adjustment was used for pair-wise comparisons when Friedman's test was significant. Wilcoxon signed-rank test was used to study the changes in dehiscence. Spearman's correlation coefficient was used to study the correlation between dehiscence and buccal cortex thickness. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS Statistics (SPSS, Inc., an IBM Company USA) Version 20 for Windows.

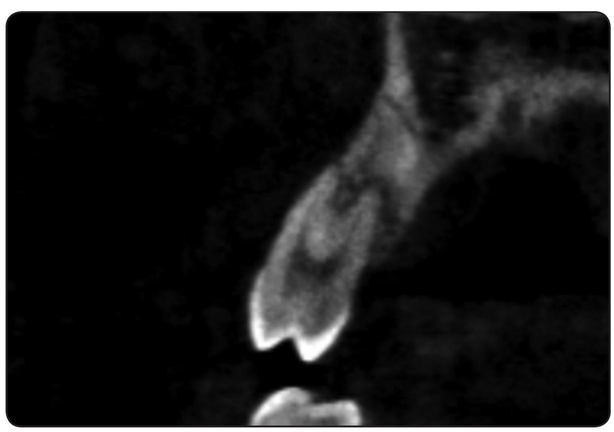

Fig. (7): Coronal CBCT image showing dehiscence of buccal bone in the cervical, middle, and apical thirds of the right second premolar.

RESULTS

The slow orthodontic maxillary expansion assisted with corticotomy and bone graft was found to be efficient in treating bilateral posterior cross-bite. This expansion was performed with four banded quad-helix appliance followed by fixed orthodontic treatment stage. Buccal bone dehiscence was noted immediately following expansion and at the end of the orthodontic treatment.

As expansion of the posterior teeth, was performed with a one piece quad-helix appliance, therefore, the dental movements of first and second premolars and the first molars were summed together, rather than each tooth individually. Also, the arch expansion affects the whole arch rather than each segment individually. The change in the arch from tapered to square was clinically noted.

Not all teeth in each segment were clinically observed to expand with same rates. Therefore, when the first molar with one/two premolars had their buccal cusps buccal to their opponents, the expansion by the quad-helix was terminated and stabilized. The average expansion period was 8.5 months. The fixed orthodontic appliance was then initiated, to continue the maxillary expansion and the other malocclusion problems. (Figure 8)

Changes by time in different parameters

The cone beam computed tomography was then used to record the different dental measurements; linear and angular. As regards intra-arch distance, there was a statistically significant increase in mean intra-arch distance at first follow-up period; 5.58± 0.77mm. From first to second follow-up periods, there was no statistically significant change in mean intra-arch distance; 1.16±0.34 mm. However, second follow-up period showed statistically significantly higher mean value than base line measurement. Thus, the total increase in the intra-arch distance till the end of orthodontic treatment was; 6.74 ± 1.11 mm.

While for the change in tipping angle, there was a statistically significant increase in mean tipping angle at first follow-up; 13.49± 0.69 degrees. From first to second follow-up periods, there was a statistically significant decrease in mean tipping angle; 8.8±1.21 degrees. However, second follow-up showed non-statistically significant difference from base line measurement, where the total increase in tipping angle was 4.69±0.52 degrees.

The cross-bite change was noted as the linear measurement that the buccal cusp tip moved buccally. There was a statistically significant increase in mean cross bite measurement at first follow-up; 3.27±0.13 mm and from first to second follow-up periods; 1.94±1.58 mm. Hence, the cross-bite correction was statistically significant, showing 5.21+1.45 mm increase.

Whereas for the bone dehiscence, there was a statistically significant increase in dehiscence from baseline to the first, as well as from first to second follow-up periods. Its score ranged from 1-2.

TABLE (1): Mean, standard deviation (SD) values and results of the changes by time in different measurements

	Base line		First follow-up		Second follow-up		*P*-value
	Mean	SD	Mean	SD	Mean	SD	
Intra-arch distance	26.12[b]	3.83	31.70[a]	4.60	32.86[a]	4.94	<0.001*
Change in tipping angle	13.13[b]	9.53	26.62[a]	10.22	17.82[b]	9.01	<0.001*
Posterior Cross bite	-2.06[c]	2.15	1.21 [b]	2.28	3.15 [a]	0.70	<0.001*
Buccal bone Dehiscence	zero		1.59	1.19	1.79	1.18	0.014*

: Significant at $P \leq 0.05$, Different superscripts in the same row are statistically significantly different

Fig. (8) Intra-oral and extra-oral photographs showing the pre, post-expnsion and at finishing orthodontic stage.

Correlation between buccal bone dehiscence and buccal bone cortex thickness

The buccal bone thickness was measured at three different regions; cervical, middle and apical, before any orthodontic intervention(T_0), (Table 2). The least thickness was recorded cervically; 1.62±0.89 and the greatest was apically; 1.90±1.34 mm.

At the first, as well as, the second follow-up periods, there was a statistically significant negative (inverse) correlation between the buccal bone dehiscence and the cervical and middle buccal cortical thicknesses. Thus, an increase in bone dehiscence was associated with a decrease in cervical and middle buccal bone cortical thicknesses. However, there was no statistically significant correlation between bone dehiscence and apical bone cortical thickness, as shown in (Table 3).

TABLE (2): Descriptive statistics of buccal bone cortex thickness (T_0)

Buccal bone cortex thickness	Mean	SD	Median	Minimum	Maximum	95% CI	
						Lower bound	Upper bound
Cervical	1.62	0.89	1.61	0.00	3.13	1.29	1.94
Middle	1.83	0.81	1.89	0.00	3.67	1.54	2.12
Apical	1.90	1.34	1.86	0.00	4.22	1.41	2.38

TABLE (3): Results of Spearman's correlation coefficient for the correlation between dehiscence and buccal bone cortex thickness

	First follow-up		Second follow-up	
	Correlation coefficient	*P*-value	Correlation coefficient	*P*-value
Cervical cortex	-0.590	<0.001*	-0.713	<0.001*
Middle cortex	-0.502	0.003*	-0.532	0.007*
Apical cortex	-0.153	0.402	-0.184	0.390

: Significant at $P \leq 0.05$

DISCUSSION

The increased need for adult orthodontic treatment, directed the orthodontists to continuously modify their mechanics through their research works. Corticotomy assisted slow maxillary expansion, using quad-helix appliance followed by fixed orthodontic mechanics, efficiently treated bilateral posterior cross-bite in adults. The bone graft applied before expansion, did not prevent the occurrence of buccal bone dehiscence.

The sample size was small in the present study, taking about one year to collect the sample, due to the low percentage of bilateral posterior cross-bite; which is found in only1.6% of the total malocclusion cases in Egyptian female patients.[1] Besides, for ethical consideration, to limit radiation exposure for research purpose, as each patient was subjected to three cone beam computed tomography scans. The number and time of CBCT scans were approved by the ethical committee, as it provides information about expansion and bone changes that was not attainable by other methods. Thus, to overcome small study sample, age; 19-20 years and sex were homogenized and all the subjects were treated and diagnosed by the same clinicians.

Previous studies claimed that corticotomy offers periodontal stability, tooth vitality and nutritive function of the bone, over osteotomy. Thus, corticotomy was used in our study, in an attempt to enhance the buccal expansion, without detrimental effects on the periodontium.

Cone beam computed tomography was used in the present study because of being a cross-sectional imaging modality which allows evaluation of the proposed outcomes such as intra-arch distance, improvement in cross-bite, and tipping angle in an accure manner. Besides, its ability to detect buccal dehiscence rather than any other radiographic modality, except multislice computed tomography, but with much lower radiation dose.

The slow expansion took an average of eight months, to correct the cross-bite. The significant tipping movement was found at this stage; 13.49±0.69 degrees, then decreased 8.8±1.21 degrees, at the second follow up period where the quad-helix was removed and the fixed orthodontic appliance was applied. Consequently, the teeth were tipped then uprightened. Previous studies claimed that over-correction of maxillary dental arch during expansion allows later uprighting of posterior teeth with fixed appliances, thus favoring bone regeneration after expansion.

Alveolar bone dehiscences were found to be present in 53.62%, when analyzing 138 skulls, ranging from 21 to 54 years of age, and more in the mandible. No correlation between high-occlusal forces and bone dehiscence, but correlation was found with modifications in bucco-lingual inclination angle's values.[28]

As was concluded from previous studies, the buccal bone dehiscence was usually accompanied maxillary expansion. [32-34] Accordingly, bone graft was applied before expansion in the present study. This was in attempt to aid bone formation, to prevent bone dehiscence. Immediately after expansion and three months following orthodontic treatment, bone dehiscence was evident. Unfortunately, bone graft did not prevent its occurrence. It did not vary in severity from first to second follow up periods. It increased significantly immediately following expansion and remained the same score till end of treatment. In previous studies, classification of bone dehiscence using cone beam computed tomography was classified into three classes I, II and III.[35] But, classification will not be enough to analyze severity of dehiscence. Therefore, the bone dehiscence was described as scores according to which areas it included as stated previously. The volumetric bone change measurement was not possible at buccal areas from cone beam radiographs.

The least buccal bone thickness was found cervically and the most was apically. The correlation between buccal bone dehiscence and cervical and middle bone thicknesses was negative. Thus, as the bone thickness increased in those areas, the dehiscence decreased. But, no correlation was noted with the apical bone thickness. Inspite of the bone dehiscence, no mobility of teeth was noted, and the teeth appeared sound throughout the clinical procedure.

Previous studies compared rapid maxillary expansion with slow expansion, but only in young patients. Vandarsal[36] reported three years after fixed appliance removal; good periodontal conditions in both groups. 20% of young patients had gingival recessions 8 to 10 years after expansion, compared to 6% in the group treated with edgewise. Shifting to adult orthodontic management of posterior cross-bite, surgically assisted rapid palatal expansion (SARPE) had always been the choice, believing it would give skeletal movement and no bone dehiscence compared to other treatment mechanics. But, unfortunately, teeth were tipped, bone dehiscence resulted and as the patient was subjected to surgery, bleeding, bone fracture and sinus exposure were common findings related to SARPE. Gautheir et al., [24] concluded that SARPE had detrimental effects on the periodontium. Significant bone dehiscence in most teeth, mostly at distal aspect of first molars was found. But the severity was not measured in any of the previous studies.

The slow expansion used in this study, gave an efficient maxillary arch expansion, with no pain, neither bleeding nor discomfort was denoted.

CONCLUSIONS

1. Corticotomy assisted palatal expansion with quad-helix appliance is an efficient expansion method for treating bilateral posterior cross-bite of the maxilla in adults.
2. The score of buccal bone dehiscence was 1-2; including the cervical only or cervical and middle regions.

3. Bone graft did not prevent the bone dehiscence accompanied by bilateral slow maxillary expansion, but whether it is less than other expansion modalities or not could not be answered from our study.

Longer follow up periods following orthodontic treatment is recommended to examine whether bone build-up would take place in the areas of bone dehiscence. It is also recommended to apply the same method in the present study and compare it with group without bone graft.

REFERENCES

1. A. H. Abdallah A, Eid F, Abdel Sayed F, "Prevalence of malocclusion and orthodontic treatment need in Egyptian school-children," Master thesis, Faculty of Dentistry, Cairo University, 2015.
2. C. Strömberg and J. Holm, "Surgically assisted, rapid maxillary expansion in adults. A retrospective long-term follow-up study.," J. Craniomaxillofac. Surg., vol. 23, no. 4, pp. 222–7, Aug. 1995.
3. D. G. Garib, J. F. C. Henriques, G. Janson, M. R. de Freitas, and A. Y. Fernandes, "Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation.," Am. J. Orthod. Dentofacial Orthop., vol. 129, no. 6, pp. 749–58, Jun. 2006.
4. K. Rungcharassaeng, J. M. Caruso, J. Y. K. Kan, J. Kim, and G. Taylor, "Factors affecting buccal bone changes of maxillary posterior teeth after rapid maxillary expansion.," Am. J. Orthod. Dentofacial Orthop., vol. 132, no. 4, p. 428. e1-8, Oct. 2007.
5. Y.-J. Seo, K.-R. Chung, S.-H. Kim, and G. Nelson, "Camouflage treatment of skeletal class III malocclusion with asymmetry using a bone-borne rapid maxillary expander.," Angle Orthod., vol. 85, no. 2, pp. 322–34, Mar. 2015.
6. J. S. Herold, "Maxillary expansion: a retrospective study of three methods of expansion and their long-term sequelae.," Br. J. Orthod., vol. 16, no. 3, pp. 195–200, Aug. 1989.
7. Fd. Uzuner and N. Darendeliler, "Dentoalveolar surgery techniques combined with orthodontic treatment: A literature review," Eur. J. Dent., vol. 7, no. 2, p. 257, 2013.
8. C. Ciambotti, P. Ngan, M. Durkee, K. Kohli, and H. Kim, "A comparison of dental and dentoalveolar changes between rapid palatal expansion and nickel-titanium palatal expansion appliances," Am. J. Orthod. Dentofac. Orthop., vol. 119, no. 1, pp. 11–20, Jan. 2001.
9. S. Einy, J. Horwitz, and D. Aizenbud, "Wilckodontics--an alternative adult orthodontic treatment method: rational and application.," Alpha Omegan, vol. 104, no. 3–4, pp.102–11.
10. Y. A. Mostafa, M. Mohamed Salah Fayed, S. Mehanni, N. N. ElBokle, and A. M. Heider, "Comparison of corticotomy-facilitated vs standard tooth-movement techniques in dogs with miniscrews as anchor units.," Am. J. Orthod. Dentofacial Orthop., vol. 136, no. 4, pp. 570–7, Oct. 2009.
11. L. Wang, W. Lee, D. Lei, Y. Liu, D.-D. Yamashita, and S. L.-K. Yen, "Tisssue responses in corticotomy- and osteotomy-assisted tooth movements in rats: Histology and immunostaining," Am. J. Orthod. Dentofac. Orthop., vol. 136, no. 6, p. 770.e1-770.e11, Dec. 2009.
12. S. M. B. E.-D. Aboul-Ela, A. R. El-Beialy, K. M. F. El-Sayed, E. M. N. Selim, N. H. EL-Mangoury, and Y. A. Mostafa, "Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics," Am. J. Orthod. Dentofac. Orthop., vol. 139, no. 2, pp. 252–259, Feb. 2011.
13. A. Hassan, S. Al-Saeed, B. Al-Maghlouth, M. Bahammam, A. Linjawi, and T. El-Bialy, "Corticotomy-assisted orthodontic treatment. A systematic review of the biological basis and clinical effectiveness," Saudi Med. J., vol. 36, no. 7, pp. 794–801, Jul. 2015.
14. A. M. L. Liem, E. J. Hoogeveen, J. Jansma, and Y. Ren, "Surgically facilitated experimental movement of teeth: systematic review," Br. J. Oral Maxillofac. Surg., vol. 53, no. 6, pp. 491–506, Jul. 2015.
15. A. P. L. M. Peron et al., "Tissue responses resulting from tooth movement surgically assisted by corticotomy and corticision in rats," Angle Orthod., vol. 87, no. 1, pp. 118–124, Jan. 2017.
16. J. H. Campbell, "Periodontally Accelerated Osteogenic Orthodontics," J. Oral Maxillofac. Surg., vol. 75, no. 1, p. 6, Jan. 2017.
17. J. Wu, J.-H. Jiang, L. Xu, C. Liang, Y. Bai, and W. Zou, "A pilot clinical study of Class III surgical patients facilitated by improved accelerated osteogenic orthodontic treatments.," Angle Orthod., vol. 85, no. 4, pp. 616–24, Jul. 2015.

18. Z. Kalemaj, C. L. DebernardI, and J. Buti, “Efficacy of surgical and non-surgical interventions on accelerating orthodontic tooth movement: a systematic review.,” Eur. J. Oral Implantol., vol. 8, no. 1, pp. 9–24, 2015.

19. R. Fuhrmann, “Three-dimensional interpretation of periodontal lesions and remodeling during orthodontic treatment. Part III.,” J. Orofac. Orthop., vol. 57, no. 4, pp. 224–37, Aug. 1996.

20. S. Akyalcin, J. S. Schaefer, J. D. English, C. R. Stephens, and S. Winkelmann, “A cone-beam computed tomography evaluation of buccal bone thickness following maxillary expansion,” Imaging Sci. Dent., vol. 43, no. 2, p. 85, Jun. 2013.

21. W. Miyama, Y. Uchida, M. Motoyoshi, K. Motozawa, M. Kato, and N. Shimizu, “Cone-beam computed tomographic evaluation of changes in maxillary alveolar bone after orthodontic treatment,” J. Oral Sci., vol. 60, no. 1, pp. 147–153, 2018.

22. J. W. Ballrick, J. M. Palomo, E. Ruch, B. D. Amberman, and M. G. Hans, “Image distortion and spatial resolution of a commercially available cone-beam computed tomography machine.,” Am. J. Orthod. Dentofacial Orthop., vol. 134, no. 4, pp. 573–82, Oct. 2008.

23. B. J. Garrett, J. M. Caruso, K. Rungcharassaeng, J. R. Farrage, J. S. Kim, and G. D. Taylor, “Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography.,” Am. J. Orthod. Dentofacial Orthop., vol. 134, no. 1, pp. 8–9, Jul. 2008.

24. C. Gauthier, R. Voyer, M. Paquette, P. Rompré, and A. Papadakis, “Periodontal effects of surgically assisted rapid palatal expansion evaluated clinically and with cone-beam computerized tomography: 6-month preliminary results,” Am. J. Orthod. Dentofac. Orthop., vol. 139, no. 4, pp. S117–S128, Apr. 2011.

25. C.C. Leung, L. Palomo, R. Griffith, and M.G. Hans, “Accuracy and reliability of cone-beam computed tomography for measuring alveolar bone height and detecting bony dehiscences and fenestrations,” Am. J. Orthod. Dentofac. Orthop., vol. 137, no. 4, pp. S109–S119, Apr. 2010.

26. A.D. Molen, “Considerations in the use of cone-beam computed tomography for buccal bone measurements,” Am. J. Orthod. Dentofac. Orthop., vol. 137, no. 4, pp. S130–S135, Apr. 2010.

27. A. M. Timock et al., “Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging.,” Am. J. Orthod. Dentofacial Orthop., vol. 140, no. 5, pp. 734–44, Nov. 2011.

28. M. Berco, P. H. Rigali, R. M. Miner, S. DeLuca, N. K. Anderson, and L. A. Will, “Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull,” Am. J. Orthod. Dentofac. Orthop., vol. 136, no. 1, p. 17.e1-17.e9, Jul. 2009.

29. R. M. Miner, S. Al Qabandi, P. H. Rigali, and L. A. Will, “Cone-beam computed tomography transverse analysis. Part I: Normative data.,” Am. J. Orthod. Dentofacial Orthop., vol. 142, no. 3, pp. 300–7, Sep. 2012.

30. N. Ye et al., “Accuracy of in-vitro tooth volumetric measurements from cone-beam computed tomography,” Am. J. Orthod. Dentofac. Orthop., vol. 142, no. 6, pp. 879–887, Dec. 2012.

31. C. S. Handelman, “Nonsurgical rapid maxillary alveolar expansion in adults: a clinical evaluation.,” Angle Orthod., vol. 67, no. 4, pp. 291-305–8, 1997.

32. G. G. Steiner, J. K. Pearson, and J. Ainamo, “Changes of the Marginal Periodontium as a Result of Labial Tooth Movement in Monkeys,” J. Periodontol., vol. 52, no. 6, pp. 314–320, Jun. 1981.

33. K. R. Greenbaum and B. U. Zachrisson, “The effect of palatal expansion therapy on the periodontal supporting tissues.,” Am. J. Orthod., vol. 81, no. 1, pp. 12–21, Jan. 1982.

34. B. Thilander, S. Nyman, T. Karring, and I. Magnusson, “Bone regeneration in alveolar bone dehiscences related to orthodontic tooth movements.,” Eur. J. Orthod., vol. 5, no. 2, pp. 105–14, May 1983.

35. A. Yagci, İ. Veli, T. Uysal, F. I. Ucar, T. Ozer, and S. Enhos, “Dehiscence and fenestration in skeletal Class I, II, and III malocclusions assessed with cone-beam computed tomography,” Angle Orthod., vol. 82, no. 1, pp. 67–74, Jan. 2012.

36. N. J. Betts, R. L. Vanarsdall, H. D. Barber, K. Higgins-Barber, and R. J. Fonseca, “Diagnosis and treatment of transverse maxillary deficiency.,” Int. J. Adult Orthodon. Orthognath. Surg., vol. 10, no. 2, pp. 75–96, 1995.