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Cone Beam Guided Corticotomy Using Piezoelectric Surgery

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Abstract

Objectives: This study was designed to compare skeletal and dental angular measurements of orthodontic treatment facilitated by cone beam guided corticotomy to that of conventional orthodontic treatment as well as treatment time**.**

Methods: Twenty female and male adult orthodontic patients with an age range of 19 to 29 years and suffering from bimaxillary protrusion recommended for first premolars extraction were randomly assigned to one of two groups: The test group was treated with a closed technique of corticotomy-facilitated orthodontics using a piezoelectric device and guided by cone beam radiography. The control group was treated with conventional orthodontic treatment. A fixed orthodontic appliance was used and anchorage was done using miniscrews. Cone beam computed tomography (CBCT) was performed for each patient of the test group. Image analysis was done using On Demand Software where linear and angular measurements were taken to virtually assess the configuration of the six anterior teeth together with the position of the lingual and mental foramen. These measurements were transferred to the study model and a surgical guide was constructed. Corticotomy was performed using the piezotome with the aid of the constructed guide. Orthodontic measurements were recorded pre- and post-treatment including total treatment time for both groups.

Results: Using a surgical guide, the surgery was a straightforward procedure. At the end of treatment, by comparing the mean change of skeletal angular measurements between the two groups, the control group showed a significant decrease in the mean of change in the facial angle compared to the test group ($p \leq 0.05$). By comparing the mean change of dental angular measurements between the two groups, the test group showed a significant decrease in SN – U1° (angle between the sella-nasion line and the maxillary incisor), and a significant increase in the interincisal angle compared to the control group ($p \leq 0.05$). Regarding the total treatment time, the test group showed a significant decrease in the mean total treatment time compared to the control group.

Conclusion: CBCT provided comprehensive information regarding anatomical relationships and individual patient findings for improved diagnosis and treatment planning. The use of a surgical template guided by the cone beam imaging provided a novel conservative technique that simplified the surgical procedure. Corticotomy-facilitated orthodontics showed marked improvement in some skeletal and dental angular measurements compared to conventional orthodontics in patients with bimaxillary protrusion, as well as a decrease in treatment time.

Keywords: Cone beam computed tomography, surgical guides, peizosurgery, corticotomy

Introduction

An increasing number of adult patients have been seeking orthodontic treatment, and a short treatment time has been a recurring request. To meet their expectations, a number of surgical techniques have been developed to accelerate orthodontic tooth movement (Sebaoun *et al.*, 2011).

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Osteotomies or corticotomies have been combined with the tooth movements to accelerate orthodontic tooth movement and facilitate difficult tooth movement as well as reshape alveolar bone. Osteotomy involves freeing bony segments to be distracted with tooth-borne distractors or aligned with orthodontic wires and springs (Lee *et al.,* 2008). Alveolar corticotomies are defined as a surgical intervention limited to the cortical portion of the alveolar bone. Contrary to osteotomies, where both cortical and trabecular bone material are removed in considerable quantities, in alveolar corticotomies the incision only pierces the cortical layer and penetrates minimally into the bone marrow (Oliveria *et al.*, 2010).

The dynamics of the physiologic tooth movement in patients who underwent conventional orthodontics is that of a cell-mediated process orchestrated predominantly within the periodontal ligament. Sustained force on a tooth translates into a periodontal ligament cell population shift wherein pleomorphic fibroblasts are converted to osteoblasts, and osteoclasts are derived from the influx of blood-borne monocytic precursors. With time, the lamina dura undergoes osteoclasis in the area of periodontal ligament "pressure," and bone apposition occurs in the areas of periodontal ligament "tension" (Krishnan and Davidovitch, 2006).

Wilcko *et al.* (2001, 2003) speculated that in case of selective decortications, tooth movement might be due to a demineralization-remineralization process. They suggested that this process would manifest as a part of the regional acceleratory phenomenon that involves the alveolar bone after being exposed to injury (corticotomy) and during active tooth movement. Because regional acceleratory phenomenon refers to reorganizing activity and the cascade of physiologic healing events that occur in tissues adjacent to the site of injury, orthodontic force application alone is a stimulant sufficient to trigger mild regional acceleratory phenomenon activity, but when tooth movement is combined with selective decortication, regional acceleratory phenomenon is maximized.

Corticotomies and corticotomy-assisted tooth movement produce transient bone resorption around the dental roots. This temporary loss of supporting alveolar bone around the dental roots is not observed with osteotomies or osteotomy-assisted tooth movement. Instead, a distal distraction site is formed (Wang *et al.*, 2008; 2009).

Orthodontic treatment is the most common way of treating bimaxillary protrusion. However, structural changes such as a decrease in the cancellous bone volume and blood supply in adults can reduce the rate of tooth movement. To overcome the limitations of orthodontic treatment, anterior segmental osteotomy is sometimes recommended. Anterior segmental osteotomy can markedly reduce the treatment period over conventional orthodontic treatment and achieve immediate improvement of the facial profile. This is one of the most attractive advantages of this technique for adult patients (Kim *et al.*, 2002). Despite the apparent clinical success of anterior segmental osteotomy, postoperative complications are as follows: ischemic necrosis of the anterior segment, wound dehiscence at the osteotomy site, and devitalization of the teeth adjacent to the osteotomy site. Recently, corticotomy-assisted orthodontic treatment with skeletal anchorage was introduced as a treatment method for bimaxillary protrusion. It represents a compromise between anterior segmental osteotomy and orthodontic treatment (Chung *et al.,* 2001). It is more conservative and reduces the ischemic complications by cutting only the cortical bone. Corticotomy allows for bending of the anterior bony segment by eliminating the cortical bone when retraction force is applied (Lee *et al.,* 2006).

Corticotomy-facilitated orthodontics is an effective treatment alternative in adults with severe malocclusion to decrease the treatment time to as little as one fourth the time usually required for conventional orthodontics, thus reducing the risk for root resorption (Oliveria *et al.,* 2010). It poses little threat to pulp vitality (Ozturk *et al.,* 2003). Moreover, ischemic damage to teeth or periodontium is reduced (Duker, 1975). It provides better retention compared to conventional orthodontic treatment. The improved stability is attributed to the increased turnover of tissues adjacent to the surgical site, and the consequent loss of tissue memory (Nazarov *et al.,* 2004).

Corticotomy-facilitated orthodontics has been employed in various forms over the past to speed up orthodontic treatments. It was first introduced in 1959 by Kole as a mean for rapid tooth movement (Kole, 1959). However, because of the invasive nature of Kole's technique, it was never widely accepted. A more recent surgical orthodontic therapy was introduced by Wilcko *et al.* (2001, 2003, 2008), which included the innovative strategy of combining corticotomy surgery with alveolar grafting in a technique referred to as accelerated osteogenic orthodontics (AOO), and more recently as periodontally accelerated osteogenic orthodontics (PAOO). This technique was advocated for comprehensive fixed orthodontic appliances in conjunction with full thickness flaps and labial and lingual corticotomies around teeth to be moved and bone grafting. (Wilcko *et al.*, 2001, 2003; Ozturk *et al.*, 2003; Fischer, 2007; Lee *et al.*, 2007; Sebaoun *et al.*, 2007).

Park *et al.* (2006) and Kim *et al.* (2009) introduced the corticision technique as a minimally invasive alternative to create surgical injury to the bone without flap reflection. This technique, although innovative, has several drawbacks, among which is difficulty to produce sharp cuts and the repeated malleting that causes dizziness after surgery and panic during it.

Vercellotti (2004) introduced piezosurgery in bone surgery. It is a new technique for corticotomies and osteotomies created by utilizing an innovative ultrasonic surgical apparatus known as the Mectron piezosurgery device. Piezosurgery was developed in response to the need to reach major levels of precision and intra-operative safety in bone surgery, as compared to that available by the traditional manual and motorized bone cutting instruments.

Vercellotti and Podesta (2007) introduced the use of piezosurgery in conjugation with flap reflection. However, the invasive nature of the procedure was still a shortcoming with several postoperative complications. Dibart *et al.* (2010) modified the technique by performing closed corticotomy where vertical osteotomy cuts were performed without flap elevation. This technique has the merits of being minimally invasive, reducing postoperative pain and swelling, ease in controlling the instrument during operation combined with reduced bleeding, and excellent tissue healing (Vercelloti 2004; Boioli *et al.*, 2004; Abbas and Moutamed, 2012). However, the elements of precision and sparing of periodontal tissue are questionable based on the fact that this technique is a closed technique with absence of flap reflection.

Cone beam computed tomography has revolutionized maxillofacial imaging, facilitated the transition of dental diagnosis from two-dimensional (2-D) to 3-D images and expanded the role of imaging from diagnosis to image guidance of operative and surgical procedures. Thus, now we are not only able to provide more accurate diagnosis with this imaging modality, but we also are able, based on the vast radiographic data, to guide and assess various surgical and clinical interventions. (Cevidanes *et al.,* 2006; Chan *et al.*, 2007 ; Cevidanes *et al.*, 2009).

Cone beam computed tomography has proven to be an appropriate tool for linear measurement (Pinsky *et al.*, 2006; Moreira *et al.*, 2009). Measurements were made of the bony covering of the mandibular anterior teeth because this region is crucial in orthodontic treatment planning. Cone beam computed tomography data at two resolutions (0.125 mm and 0.4 mm voxels) were collected from eight intact cadaver heads. The vertical position of the mucogingival junction was clinically assessed. After removal of the gingiva, vertical and horizontal bony measurements were taken, and the buccal alveolar bone margin was determined. Anatomic bony measures were compared with the CBCT measures, and the correlation of the mucogingival junction measures to the buccal alveolar bone margin measures was evaluated. The results showed that the bony measures obtained with CBCT were accurate and differed only slightly from the physical findings. Thus, CBCT renders anatomic measurements reliably and from which linear measurements can be taken accurately (Patcas *et al.*, 2012).

In late 2011, Sebaoun *et al.* recommended the use of CBCT for preoperative diagnosis to locate areas of close root proximity, bone foramen, and to assess the quantity and location of areas where bone requires augmentation. The utilization of CBCT explained in this novel approach was introduced to provide the clinician performing closed corticotomy with an insight of challenging areas of tooth anatomy and bone foramina, and to guide him through the surgical intervention.

The aim of the present study was to compare skeletal and dental angular measurements of orthodontic treatment facilitated by cone beam guided corticotomy to that of conventional orthodontic treatment as well as treatment time.

Materials and methods

The participants in this double blind study consisted of 20 adult orthodontic patients (4 males and 16 females) suffering from bimaxillary protrusion recommended for first premolars extraction with an age range of 22.4 ± 2.36 years. The participants were selected from patients seeking orthodontic treatment in the outpatient clinic of the Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University - Girls' Branch.

The participants were randomly assigned to the test or control groups by Microsoft Excel 2010. The test group was treated with a closed technique of corticotomy-facilitated orthodontics using a piezoelectric device and guided by cone beam radiography. The control group was treated with conventional orthodontic treatment.

Inclusion criteria were orthodontic treatment entailing the extraction of first premolar teeth, full eruption of all permanent teeth (third molars were not considered), good oral hygiene, adequate gingival thickness, absence of periodontal disease, no previous orthodontic treatment, no previous periodontal surgeries, no regular administration of non-steroidal anti-inflammatory drugs (NSAIDs).

The patients of both groups were informed of the surgical procedure, the risks, and its advantages and disadvantages. Patients signed informed consent forms before the initiation of treatment. The experimental protocol was approved by the Ethical Committee of the Faculty of Dentistry, Al Azhar University in January 2010.

Records

Pre-treatment and post-treatment records were taken for all selected patients and included extra-oral and intra-oral photographs, orthodontic study casts, standardized digital lateral cephalometry, panoramic radiograph, and periodontal examination (plaque index, gingival index, probing depth). Oral hygiene instruction and scaling was provided if needed.

Cephalometric analysis

All cephalograms were traced by the same author. Cephalometric landmarks were located, identified and marked. Linear and angular measurements were assessed according to the McNamara analysis. Four skeletal angular and three dental measurements were selected.

Skeletal angular measurements

- SNA (sella-nasion subspinale, point A) angle: The anteroposterior position to the maxilla relative to the cranial base.
- SNB (sella-nasion supramentale, point B) angle: The anteroposterior position of the mandible relative to the cranial base.
- ANB (point A-nasion-point B) angle: The antero posterior relationship of the maxilla to the mandible.
- Facial depth angle: The angle where the facial line (N-Pg) intersects the Frankfort horizontal plane.

Dental angular measurements

- SN – U1: Measured from the sella-nasion line to the maxillary incisor angle.
- MP – L1: Mandibular plane to mandibular incisor tip.
- Interincisal angle: The angle between the long axis of the lower and upper incisors.

Orthodontic appliance

A fixed orthodontic appliance (G and H Wire Company, USA) with the same mechanics and anchorage was inserted using miniscrews (SDS Ormco, and Glendora, California, USA) for all subjects in both groups (*Figure 1*).

Figure 1. A clinical photograph showing upper and lower miniscrews

CBCT scanning

Cone beam computed tomography imaging for the maxillofacial region of each patient was performed using Scanora® 3DXL (Soredex Finland). The detector of this machine is composed of a complementary metallic oxide (CMOS) flat panel with isotropic voxel size 133 μm. The x-ray tube used had an intensity of 16 mA, kilovoltage of 85 KVP, and a focal spot sized 0.5 mm. The scanning time was 18 seconds of pulsed exposure to scan a focal volume (FOV) of 13 cm height × 14.5 cm width × 14.5 cm depth.

Software manipulation and secondary reconstruction

The raw DICOM data images obtained from CBCT were imported to the on-demand 3-D software (Cybermed, South Korea) for secondary reconstruction. The multiplanar reconstruction screen (displaying the volumetric data set as axial, coronal, sagittal and 3-D volume rendering) was used for all the CBCT images together with reconstructed panoramic radiographic images. Navigation was done through narrow slice reconstructed panoramic images of each patient until images of the six anterior teeth were viewed clearly and distinctly. The image layer showing the maximum length as well as width of the root of the six anterior teeth was selected for preliminary measurements.

Image analysis

Linear and angular measurements of anatomically challenging areas:

- Several linear measurements (in mm) were assessed using the distance-measuring tool of the software (*Figure 2*):
- Length of root from midpoint of line drawn through cementoenamel junction (CEJ) to tip of root (*Figure 3a*).
- Maximum convexity (bulge) of root (*Figure 3b*).
- Distance from midpoint of line drawn from maximum convexity to midpoint of line drawn through CEJ (*Figure 3c*).
- Space between two neighboring teeth at narrowest point (*Figure 3d*).
- Distance between narrowest point between two teeth and CEJ (*Figure 3e*).
- Degree of mesial and distal inclination of each of six anterior teeth defined by measuring angle between perpendicular line drawn from midpoint of CEJ and another line drawn from same point on CEJ to apex of tooth. This angle was measured in degrees (*Figure 3f*).
- Distance from middle of mental foramen to alveolar ridge.

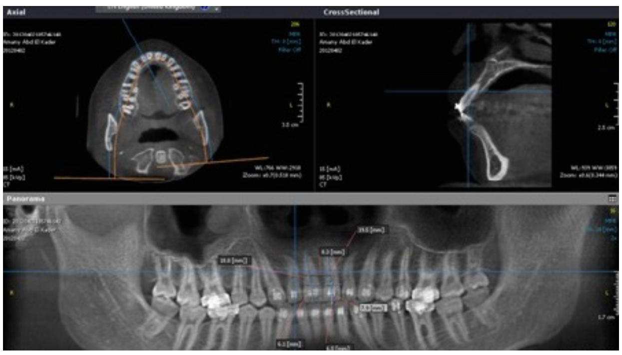

Figure 2. Reformatted panorama of cone beam computed tomography showing linear and angular measurements.

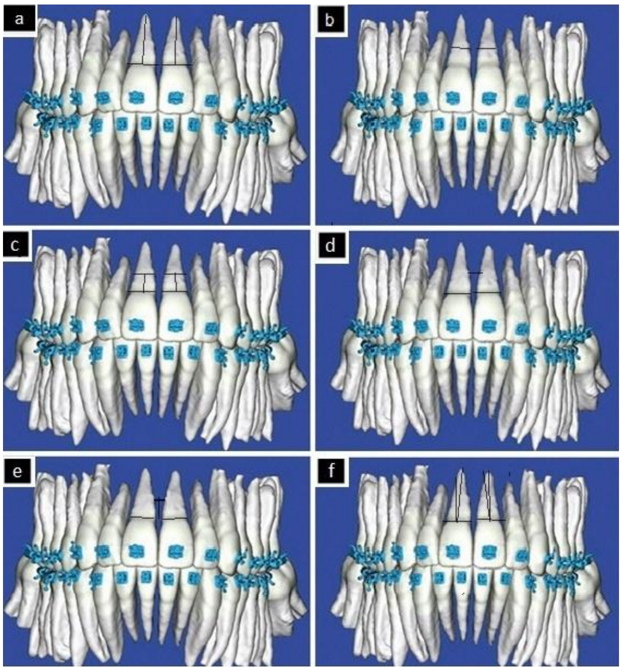

Figure 3. Diagrammatic representation of radiographic measurements: a) Length of root; b) Maximum convexity of the root; c) Distance from midpoint of line drawn from maximum convexity to midpoint of line drawn through CEJ; d) Space between two neighboring teeth at the narrowest point; e) Angle measuring the degree of inclination. CEJ, cementoenamel junction

All measurements were viewed on 3-D reconstructed images for verification of these measurements in different skull orientations, and were repeated after one week by the same observer to assess the reproducibility of measurements.

Transfer coping and cone beam surgical guide construction

After finishing the leveling and alignment stage of the orthodontic treatment plan, the construction of the surgical guide was started immediately after the extraction of the upper and lower right and left first premolars. Cone beam radiographs were taken of the test group patients to obtain a complete analysis of measurements, including the root length, diameter, and configuration of the six anterior upper and lower teeth as well as the position of mental and lingual foramina in relation to the ridge. An orthodontic study cast was obtained for each patient to be used to construct the surgical guide. According to data taken from the cone beam analyses, the roots of the six anterior teeth were demarcated by a pencil on the buccal and palatal sides of the upper and lower casts (*Figure 4a, 4b*). Vertical lines between the roots were drawn sparing the lingual and mental foramina. These lines were guides for the vertical slices of the corticotomy, which started 3 mm below the interdental papilla of each tooth in the area representing the alveolar bone on the upper and lower casts. Using a vacuum machine, a surgical guide was constructed using acrylic sheets with a thickness of 0.5 inch on the upper and lower casts, and the vertical lines drawn between the six anterior teeth of the upper and lower casts on the constructed splint guides were traced (*Figure 4c, 4d*). After removal of the constructed splint guides from their casts, a diamond cutting disk was used to follow the lines drawn on these guide splints. These lines represented the vertical slices of the corticotomy (Figure *4e, 4f*).

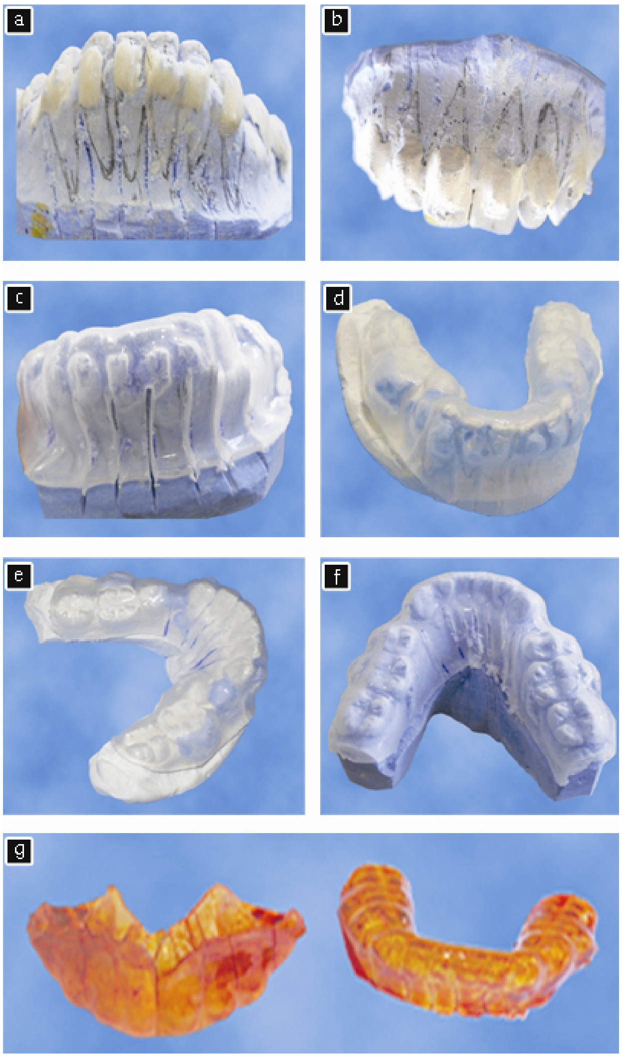

Figure 4. Steps of cone beam surgical guide construction: (a and b) Roots of the six anterior teeth drawn on the cast using cone beam measurements; (c and d) Buccal view of the surgical guide constructed with acrylic sheet on the upper and lower casts; (e and f) Lingual view of the surgical guide; (g) Upper and lower surgical guides before surgery.

Surgical procedure

Local anesthesia infiltration of 4% articaine hydrochloride with 1/200,000 epinephrine (Septocaine®, Septenest N, Septodont, Cairo, Egypt) was applied in the mucobuccal fold of the six anterior upper and lower teeth and in the palatal and lingual sides of the upper and lower teeth without premedication or sedation. The cone beam surgical guide was sterilized with a Betadine mouthwash as antiseptic solution (*Figure 4g*). The patient wore the surgical guide in both jaws and the incision of vertical cuts was marked by a surgical blade No. 15. The corticotomy was done using the tip of the piezotome 2 device (Piezo2-2HP®/ Mectron-Piezosurgery) to pass marked incisions under copious saline irrigation to a depth of 2 mm on the buccal and lingual sides of both arches (*Figure 5a, 5b, 5c, 5d*).

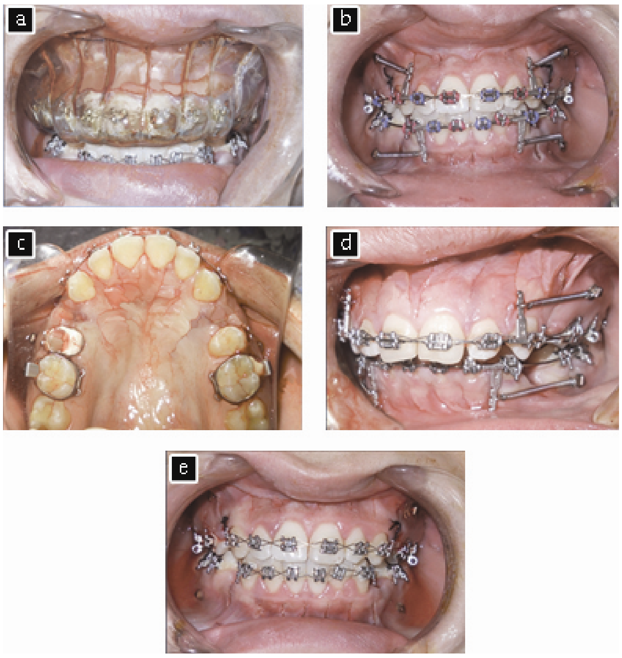

Figure 5. (a) Clinical photograph showing the cone beam surgical guide in patient's mouth and the incision for vertical cut marked; (b) Clinical photographs showing buccal view of the vertical cut in the upper and lower jaws; (c) Clinical photograph showing palatal view of the vertical cut in the upper jaw; (d, e) Clinical photographs showing final view after the operation and activation of the appliance.

Postsurgical instructions

A systemic antibiotic (500 mg amoxicillin and 500 mg clavulanate potassium; Augmentin®, Medical Union Pharma, GlaxoSmithKline, Ireland) every 12 hours for 5 days after surgery, and an analgesic (Panadol®, Alexandria Cooperation, GlaxoSmithKline, Ireland) were prescribed. Patients were instructed to rinse twice daily for 2 minutes, for a period of 2 weeks, using 0.12% chlorhexidine gluconate mouthwash.

Activation of the orthodontic appliance

Space closure was initiated immediately after the surgical procedure. Orthodontic adjustments were performed every 2 weeks.

Statistical analysis

The cephalometric radiographs were randomly selected, retraced, and digitized by the same operator after a period of one month. Data were presented as mean and standard deviation (SD) values. The resulting data of the current study were collected, tabulated and statistically analyzed. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. For parametric data, a paired t-test was used to study the changes after treatment within each group. For non-parametric data, the Wilcoxon signed-rank test was used to study the changes after treatment within each group. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Postoperatively, minimal swelling of the oral tissues was visible in the test group on the day after surgery. Discomfort was reported by the patients only on the day of surgery. Using the surgical guide, the surgery was a straightforward procedure and no peri-operative changes were made by the operator.

By the end of treatment, the mean change in SNB for the test group was -1.71 ± 1.5°, and for the control group it was -1.29 ± 0.95°, while the mean change in SNA was 0.43 ± 0.79° and -0.86 ± 0.69° for the test and the control group respectively. The mean change in the ANB was -1.29 ± 1.11° for the test group and -0.43 ± 0.98° for the control group. As for the facial angle, the mean change was -0.14 ± 0.9° for the test group and -3.29 ± 2.87° for the control group. The control group showed a significant decrease in the facial angle compared to the test group (*Table 1, Figure 6*). Patients were pleased with the esthetic results *(Figure 7).*

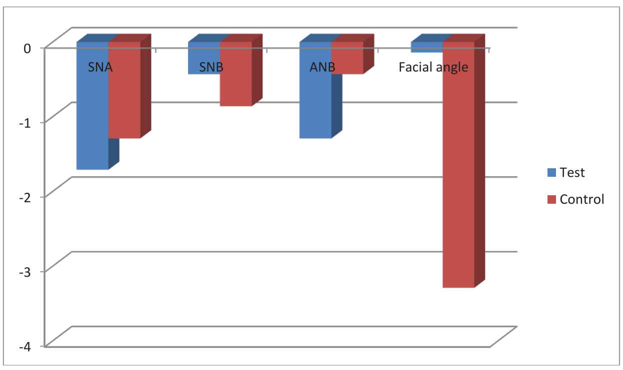

Figure 6. Bar chart showing the mean change in skeletal angular measurements in the test and control groups.

Table 1. The means of skeletal angular measurements, standard deviation (SD) values and results of comparison between the two groups.

Skeletal measurement	Test group					Control group					Mean change				
	Before		After		*p*	Before		After		*p*	Test		Control		*p*
	Mean	SD	Mean	SD		mean	SD	mean	SD		mean	SD	mean	SD	
SNA°	84.14	2.1	82.43	2.88	**0.023***	78.86	2.12	77.57	2.30	**0.012***	-1.71	1.50	-1.29	0.95	**0.620**
SNB°	78.86	2.27	78.43	2.64	**0.200**	74.00	2.24	73.14	2.12	**0.017***	-0.43	0.79	-0.86	0.69	**0.456**
ANB°	5.29	1.7	4.00	1.83	**0.041***	4.86	1.95	4.43	1.72	**0.257**	-1.29	1.11	-0.43	0.98	**0.209**
Facial angle°	84.57	2.30	84.43	2.44	**0.689**	84.71	2.81	81.43	3.31	**0.023***	-0.14	0.90	-3.29	2.87	**0.017***

*$p \leq 0.05$; SNA°, sella-nasion subspinale, point A; SNB°, sella-nasion supramentale, point B; ANB°, point A-nasion-point B

Table 2. The means of dental measurements, standard deviation (SD) values and results of comparison between the two groups.

Dental measure-ment	Test group					Control group					Mean change				
	Before		After		*p*	Before		After		*p*	Test		Control		*p*
	Mean	SD	Mean	SD		Mean	SD	mean	SD		Mean	SD	mean	SD	
SN – U1°	113.71	2.21	97.71	8.42	**0.001***	109.14	5.73	100.57	7.72	**0.117**	-16.00	7.07	-8.57	12.41	**0.029***
MP – L1°	106.43	4.39	97.86	4.41	**0.007***	100.86	5.52	98.71	7.06	**0.407**	-8.57	5.68	-2.14	6.36	**0.165**
Interincisal angle°	105.14	5.30	129.57	6.85	**<0.001***	111.71	7.36	123.14	11.19	**0.105**	24.43	6.50	11.43	15.86	**0.038***

*$p \leq 0.05$; SN – U1°, sella-nasion — upper incisor; MP – L1°, mandibular plane – lower incisor

Figure 7. Comparison of facial profile pre-treatment and post-treatment for the test group.

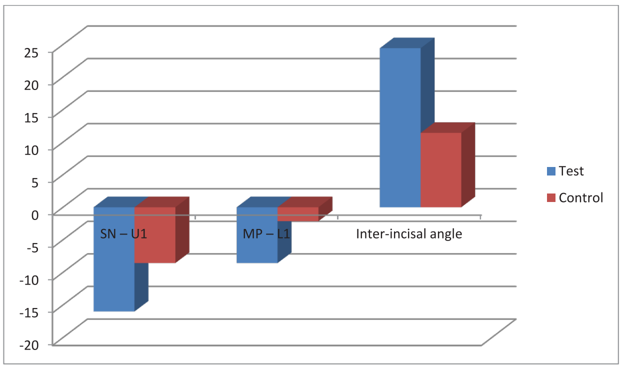

Figure 8. Bar chart showing the mean change in dental measurements in the test and control groups.

The mean change in dental angular measurements was -16 ± 7.07° for the test group, while it was -8.57 ± 12.41° for the control group. The MP-L1 was -8.57 ± 5.68° for the test group, and -2.14 ± 6.36° for the control group. The interincisal angle was 24.43 ± 6.5° and 11.43 ± 15.86° for the test and control group respectively (*Figure 8*).

The test group showed a significant decrease in SN – U1° compared to the control group. The test group showed also a significant increase in the interincisal angle in comparison to the control group (*Table 2, Figure 7*).

As for the treatment time, the test group showed a significant decrease in the total treatment time compared to the control group. The mean time for the test group was 43.43 ± 2.99 weeks, while it was 55.57 ± 1.9 weeks for the control group.

Discussion

Despite the efficiency of conventional techniques of corticotomies, postoperative complications and the clinically aggressive nature of these methods, related to the elevation of mucoperiosteal flaps and the duration of the intervention, caused reluctance among patients and within the profession.

Several studies reported adverse effects to the periodontium after open corticotomy. These ranged from slight interdental bone loss and loss of attached gingiva, to periodontal defects observed in some cases with short interdental distance (Dorfman *et al.,* 1979). Some gingival recession, loss of interdental papillae, or alveolar bone resorption may result, owing to reduced blood flow caused by periosteal elevation, or thermal damage during the surgical procedure (Kawakami *et al.*, 1996).

Orthodontic microsurgery is associated with minimal morbidity. Surgical control for piezoelectric surgery is easier than conventional surgical burs for selective alveolar corticotomies. Heat generation during bone cutting with piezoelectric surgery is much less compared to surgical burs. Thus, the risk of bone damage as a result of overheating is reduced (Abbas and Moutamed, 2012).

Cone beam computed tomography provides 3-D imaging of dental structures with submillimeter resolution images of high diagnostic quality, a short scanning time, reduced radiation exposure, and low cost compared with conventional CT, a variable field of view (FOV), voxel isotropy, 3-D localization, accuracy, variable slice thickness viewing, multiplanar reformatting, and 1:1 life-sized image analysis (Sukovic, 2003; Scarfe and Farman, 2008).

Lagravere *et al.* (2008) evaluated the accuracy of measurements made on 9-inch and 12-inch CBCT images compared with measurements made on a coordinate measuring machine. They found no significant statistical differences between the linear and angular measurements from the coordinate measuring machine and the NewTom 3G (Aperio Services, Verona, Italy) images. Hence, they concluded that the NewTom 3G produces a 1:1 image-to-reality ratio.

To determine the accuracy and reliability of measurements obtained from 3-D CBCT for different head orientations, stainless steel wires were fixed to a dry skull at different places. The skull was scanned by using CBCT in the centered position and five other positions. Two methods were used to determine the accuracy of measurements on the virtual 3-D skull scanned in different positions. In the first method, 12 linear distances were compared on the physical skull and the 3-D virtual skull in the centered and the other scanning positions. In the second method, registration of each of the five positions on the centered position was done separately, and coordinates of 11 landmarks were identified in each position and compared with the centered position. Data gathered from the two methods were compared statistically. It was concluded that accuracy and reliability of CBCT measurements are not affected by changing the skull orientation (El Beialy *et al.*, 2011).

Accuracy of corticomy cuts requires insight of anatomical structures and root teeth morphology. Cone beam computed tomography satisfies the demands of localizing the areas of root proximity in three dimensions. Very close proximity of roots were noted in more than one patient in the current study that would not be detected even with flap reflection in open corticotomy. Furthermore, critical foramina such as the lingual and mental foramen could be accurately demarcated. These recorded data were utilized for surgical guide template construction.

Computer-aided surgery was first introduced in dentistry with the advent and rapid development of implant therapy. In these techniques, implant placement is first simulated on cone beam images and then transferred to the operation site using either navigation or surgical templates, or so-called drill-guides (Van Steenberghe *et al.*, 2003 and Van Assche, 2007). Similarly, a surgical guide was constructed in the current study using measurements transferred from cone beam images. Surgical guidance could prevent jeopardizing teeth and the periodontium, and preserve the root integrity, which when coupled with the advantages of piezo-corticotomy could optimize the whole treatment outcome.

The results of the present study revealed that by the end of treatment the test group showed a significant reduction in the ANB. The mean of change was -1.29° ± 1.11° Reduction in the ANB angle revealed change in the anteroposterior relation of both the maxilla and mandible to the cranial base, which provided a more esthetic change in the corticotomy group than the control group. Furthermore, by comparing the two groups, the control group showed an increase in the facial angle compared with the test group. The facial angle indicates the degree of recession or protrusion of the mandible in relation to the upper face. The possible cause for these results may be related to the fact that corticotomy can lead to repositioning of both A and B points more posteriorly than conventional orthodontics.

These results disagree with those of Lee *et al.* (2007), who compared conventional orthodontic treatment outcomes, anterior segmental osteotomy, and corticotomy-assisted orthodontic treatment for patients with bimaxillary dentoalveolar protrusion, and found that the mean change of ANB was 1.78 ± 1.74° in the corticotomy-assisted group, while this change was -1.34 ± 1.63° in the osteotomy group.

In the current study, the dental angular measurements showed a significant decrease in the mean SN – U1° and MP – L1° measurements. There was also a significant increase in mean interincisal angle measurements. Comparing the two groups, the test group showed a significant decrease in SN – U1°and a significant increase in the interincisal angle compared to the control group.

The increase in interincisal angle in the control group was a result of upper and lower incisor retroclination. Difference of tipping between the two groups can be explained by the controlled tipping of the upper and lower incisors and the change in the upper and lower alveolar ridge angle. This is in accordance with Lee *et al.* (2007), who found that corticotomy-assisted orthodontic treatment causes more lingual bending of the alveolar bone than conventional orthodontic treatment. This suggests that corticotomy-assisted orthodontic treatment with skeletal anchorage can be advantageous for achieving the maximum retraction of upper and lower incisors in patients with severe proclination of upper and lower incisors and alveolar bone.

The results of the current study revealed that the test group showed a statistically significant decrease in the treatment time compared to the control group. These results agreed with those of Lino *et al*. (2007), who reported significant acceleration of tooth movement in their animal study. The findings corroborate the clinical observations of Wilcko *et al*. (2001; 2003) who reported significant reductions in treatment time with corticotomy-facilitated orthodontics.

Conclusion

From this study it could be concluded that CBCT provided comprehensive information regarding anatomical relationships and individual patient findings for improved diagnosis and treatment planning. The use of surgical templates guided by cone beam imaging provided a novel conservative technique that simplified the surgical procedure. Marked improvement of some skeletal and dental angular measurements were reached using corticotomy-facilitated orthodontics in patients with bimaxillary protrusion. The technique allowed innovative orthodontic correction of severe malocclusions in less time than conventional methods.

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