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Evaluation of the effects of orthodontic forced eruption (OFE) with the straight-wire appliance on the dimensional changes of the alveolar process when used post-extraction of compromised maxillary anterior teeth and development of implant site: A clinical CBCT study.

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ABSTRACT: Objective: To investigate the effects of orthodontic forced eruption (OFE) with the straight-wire appliance on the dimensional changes of the alveolar process when used post-extraction of compromised maxillary anterior teeth and development of implant site.

Material and Methods: Cone-beam computed tomography (CBCT) scans of 10 patients undergoing extraction of 20compromised maxillary anterior teeth were obtained before and immediately after OFE. CBCT sagittal cross sections were analysed for measuring alveolar plate height and thickness on the buccal and palatal socket walls.

Results: Calculation of sample size was done as discussed with statistician. Statistical analysiswas done using paired t-test and Wilcoxon test for assessment of alveolar plate dimensional changes.OFE caused statistically significant reduction of the buccal alveolar plate height (2.05 ± 1.83 mm) and significant increase of the palatal alveolar plate height (1.21 ± 2.41 mm) in the central tooth socket areas. Buccal reduction was associated positively to the baseline root length and negatively to the thickness of the corresponding plate in the apical level. A non-significant increase was noted in both buccal (0.24± 0.93 mm) and palatal (0.65 ± 1.59 mm) proximal bone. Inadequate buccal bone support hindered immediate implant placement in six sockets; however, all inserted implants showed adequate and gradually increasing stability from insertion to final restoration.

Conclusion: In around 35% of treated sockets, implant placement has reportedly been inhibited due to compromised buccal plate height.[9,10] Thus, OFE proves to be a favourable modality to enhance palatal and proximal alveolar bone height with significant reduction in the buccal plate height.

Keywords: Cone-beam computed tomography (CBCT), orthodontic forced eruption (OFE), immediate implant.

I. INTRODUCTION

The eruption pattern and presence of teeth are two governing factors for development of alveolar process.[1,2]Various canine models have been thoroughly investigated to study the post extraction sequence of alveolar process alterations along with histologic examination of tissue remodelling. In accordance with these studies, the first filled woven bone into the socket is soon replaced by lamellar bone which is accompanied with resorption of outer surfaces of both bone walls. Thus, there is significant reduction in vertical and horizontal dimensions.[3, 4]Consequently, the overall size and dimensions of alveolar process change regardless of flap elevation or flapless techniques prevalent these days.[5,6] Post-extraction dimensional changes of the anterior maxilla involve asymmetrically greater resorption of the buccal surfaces than the palatal [7] resulting in a distinct shift of the centre of the upper edentulous ridge towards the palate.[8]Ample of literature is available online presenting various methods that have been employed to evaluate bone remodelling after single tooth extractions.[9,10]

With the advent of sophisticated three-dimensional (3-D) radiographic techniques, like cone-beam computed tomography (CBCT),3-D quantification of post-extraction ridge alterations in the maxillary aesthetic zone has become easier.[11] Chappuis et al. [12] showed that CBCTs in the anterior maxilla depicted a vertical ridge loss 3.5 times greater than that reported with other methods and subjects with thin-wall phenotypes presented significantly greater vertical bone resorption. A series of tissue events occur during and after the placement and incorporation of different xenografts (Bio-Oss® Collagen). 4 weeks post-operatively, biopsy sections have demonstrated 45% newly formed bone with 37% of connective tissue components. Particles of xenograft used serve as scaffold for migration of osteoblasts that aid in new bone formation. [13]With the use of barrier membranes, a significant contraction of the marginal surface area was prevented after 3-6 months of xenograft healing, grafting procedures failed to prevent resorption of the alveolar crest while large numbers of Bio-Oss particles were still present [14, 15]. Using the same xenograft for over-augmentation of the buccal bone in conjunction with socket fill failed to compensate for post-extraction changes [16].This was thought to be prevented by using autologous bone grafts, which are considered the gold standard in bone defect repair [17]yet ridge resorption after tooth extraction was evident even with autologous grafts as well[18]. Even though socket preservation procedures could possibly lessen vertical and horizontal contraction, they did not manage to totally prevent alveolar resorption at the grafted sites and recommendations regarding the ideal type of biomaterial or surgical technique could not be robustly supported [19, 20].

Orthodontic forced eruption (OFE) has been proposed initially as a method to resolve infrabony periodontal defects [21] and assist in crown lengthening of traumatized and/or non-restorable teeth [22]. The method was further applied as a non-invasive alternative for implant site development in the anterior maxilla. Alveolar ridge preservation and reconstruction were advocated to be feasible in a more predictable and conservative manner prior to implant insertion [23, 24]. The process described in the available literature involves the placement of orthodontic fixed appliances that facilitate gradual extrusion and final extraction of compromised teeth. Simultaneously, augmentation of both hard and soft tissues has been proposed through coronal relocation of the alveolar crest and gingival margins in the corresponding sites [23, 25]. Nonetheless, the available literature on the efficacy of OFE by using the periodontal ligament apparatus of compromised teeth for enhancing alveolar reconstruction and new bone formation is mainly derived from case reports [26], whereas the biomechanical considerations of orthodontic tooth movement regarding the magnitude and direction of forces are not yet clarified. Hence, the primary outcome of this study was to assess by using CBCTs the pattern of alveolar ridge remodelling in the anterior maxillary region following tooth extraction with OFE. Secondary outcomes included the efficacy of immediate implant insertion in the treated sockets and their subsequent stability.

II. MATERIALS AND METHODS

Inclusion criteria

- Minimum age required was 18 years not less,
- Non-restorable and in need of maxillary anterior teeth (only central incisors, lateral incisors, and canines) extractions, of minimum 4 mm bone support,
- Intact buccal and palatal alveolar bone plates evident on initial CBCT,
- No previous orthodontic treatment, and
- Non-smokers.

Exclusion criteria

- Patients with the following characteristics were excluded from selection: smoking (current or for the past 5 years),
- alcohol or other substance abuse,
- bone metabolic disease or medication affecting bone metabolism,
- other systemic disease (diabetes, autoimmune disease),
- Medical history of malignancy, radiotherapy, chemotherapy,
- Periapical pathology, active periodontal disease, and inadequate oral hygiene.

All patients who fulfilled the earlier criteria were given thorough explanation of the study protocol, treatment stages, possible advantages or ineffectiveness, and complications of the procedures. Written informed consent was obtained.

CBCT acquisition and image reconstruction

CBCT scans were obtained with the PaX-i3D Smart (Cone Beam 3D Imaging, VatechEzDent M, Malaysia) imaging system. It is a common practice in implant surgery to perform an initial CBCT at baseline for patient evaluation and initial consultation and then a second one after tooth extraction or guided bone regeneration (GBR) and augmentation procedures [11, 12, 19, 20].So, initial CBCT was taken prior to any type of treatment and final CBCT was taken 4 weeks after the completion of OFE and immediately prior to implant placement. This facilitatesprecise representation of alterations induced by any intervention since initial consultation (extractions, GBR) for assessing whether conducive and favourable conditions exist for implant placement and also decide the size and type of implants or construct surgical guides; thus, the radiation dose could be justified and as low as reasonably achievable principle was followed. Each patient was examined in an upright, standardized position using a beam of light. The horizontal reference beam coincided with the Frankfort horizontal plane (a line defined by the superior border of the external auditory meatus and the infraorbital rim) set parallel to the floor and the vertical reference beam coincided with facial midline. Ideal head position was followed by fixing the head to the scanners hard frame so as to maintain stability during the scanning procedure. Scanner settings were at 110 kV, 1.71–7.60 5 mA, exposure time 3.6 seconds, field of view of 12 cm, voxel size 0.15 mm, signal greyscale 12 bit, and slice thickness 1 mm. The CBCT data were saved as Digital Imaging and Communications in Medicine (DICOM) files and 3D reconstructions were attained with the NNT Viewer software (Cone Beam 3D Imaging). Further standardization was determined by head reorientation on the software. On the lateral view, the Frankfurt horizontal plane, passing from each subject’s right portion and right orbitale points, was set parallel to the software’s horizontal reference line. On the coronal view, the plane passing through crista galli was set parallel to the software’s vertical reference line [27,28]. In this way any pitch, roll and/or yaw discrepancies during CBCT exposure were adjusted; hence, all sagittal cross-sectional slices and images were acquired on this software reoriented and standardized head position.

Intervention Orthodontic procedures

Pre-adjusted, conventional orthodontic fixed appliances (Roth prescription used for all teeth but canines, which were bonded with standard edgewise brackets with 0° tip and torque, 0.022 inch slot) were bonded on the buccal surfaces of the maxillary dental arch. Prior to the initiation of OFE, complete levelling and alignment of the dentition was performed with NiTi wires. Adjustments were scheduled every 4 weeks for sequentially increasing the cross-sectional size of the wires. Then, gradual extrusion of the corresponding teeth was achieved by rebonding their brackets in a more gingival position and refitting the working orthodontic wires (0.017 × 0.025 inch NiTi) inside the bracket slots as per the straight-wire technique for orthodontic extrusion (36). In order to facilitate optimal extrusive forces (10-15g/ tooth), rebonding was carried out at a crown level. Measurement of extrusive forces was done with a gauge. Coronoplastyof the incisal and palatal tooth surfaces was performed in order to avoid premature contacts and traumatic occlusion on each reactivation appointment. Endodontic treatment had already been performed 4–8 weeks before initiation of orthodontic treatment to refrain patients from pulp sensitivity due to the enamel reduction. Upon completion of OFE, orthodontic appliances were left in situ for 4 weeks to allow maturation of the newly formed bone.

Surgical procedures

A detailed and comprehensive clinical examination was executed 4 weeks after completion of OFE accompanied with radiographic acquisition of the final CBCT scan. One hour preoperatively, patients were advised to initiate prophylactic antibiotic and analgesic therapy. Oral disinfection was performed with 0.2% chlorhexidine digluconate mouthwash. Tooth extraction was performed with minor incision of the circumferential periodontal ligament fibers as there was no bone support. Immediate implant placementwas performed with the flapless technique by using the palatal bone as a guide for pre-drilling. All implants were of 13 mm length and 4 mm diameter in central incisor and canine sites and of 3.25 mm diameter in lateral incisor sites.

Implant Stability

Torque for implant insertion was set on 35 Ncm. Implant stability was measured with resonance frequency analysis after attaching the appropriate SmartPeg™ on the implant neck and implant stability quotient (ISQ) was recorded with the Osstell™ Mentor device (Integration Diagnostics AB, Göteborg, Sweden). ISQ was measured both on the mesiodistal and the buccolingual direction as per the manufacturer’s instructions immediately after implant placement, on provisionalization and at final prosthetic restoration.

Provisionalization and final prosthetic restoration

Monophase polyether impressions were taken immediately after implant placement (Impregum™ Soft Polyether Impression Material; 3M ESPE, St. Paul, Minnesota, USA) and provisional restorations free of contacts in all movements were delivered to the patients within 24–48 hours post-surgery. Metal–ceramic final prosthetic restorations were inserted 6 months after implant placement.

III. RESULTS

All patients who had accepted to participate in the study concluded the orthodontic treatment with the extraction of the relevant teeth through the application of OFE with no missing data.A total of 235 images (107 from the central socket areas and 128 from the proximal areas) were acquired and measured in the sagittal CBCT cross-sectional slices. On each time point, 51 images were from the central socket areas and 64 images were from the proximal areas. According to the Shapiro–Wilk test, data of all variables showed normal distribution.

	N	Initial (T1) Mean ± SD (mm)	Final (T2) Mean ± SD (mm)	T2−T1 Mean ± SD (mm)	Lower bound	Upper bound	p-value
Buccal height (central)	**20**	**10.96 ± 2.48**	**8.91 ± 2.92**	**−2.05 ± 1.83**	**−2.89**	**−1.01**	**<0.001***
Palatal height (central)	**20**	**12.48 ± 2.48**	**13.69 ± 2.16**	**1.21 ± 2.41**	**0.07**	**2.55**	**0.04**
Buccal height (interproximal)	**20**	**10.86 ± 1.99**	**11.10 ± 2.11**	**0.24 ± 0.93**	**−0.24**	**0.70**	**0.33**
Palatal height (interproximal)	**20**	**12.79 ± 1.89**	**13.44 ± 1.70**	**0.65 ± 1.59**	**−0.18**	**1.44**	**0.12**

Table 1. Initial (T1), final (T2), and difference (T2−T1) of mean values with standard deviations (SDs) for alveolar ridge height measurements in the central and interproximal cross sections of the sockets. N, number of examined sockets; P, statistical significance

IV. DISCUSSION

This prospective, observational clinical trial is one of the few studies done using CBCT for evaluation of the dimensional alterations in the anterior maxillary alveolar ridge after tooth extraction with orthodontic forces (OFE). In this study OFE was delivered in accordance with the method proposed in the current literature using the straight-wire appliance. In this study, quantitative evaluation of the sagittal CBCT cross sections was used, which is a common practice in implant surgery for the evaluation of the anatomy and dimension of the alveolar process at baseline and after tooth extractions or any augmentation methods prior to implant placement [11, 12, 19, 20]. Tooth extractions with OFE significantly decreased the buccal alveolar bone height in such a way that in some cases did not allow implant placement. In this study, the mean buccal bone loss that occurred with OFE was slightly greater compared to simple extractions; however, the significant gain in palatal bone and minor augmentation in proximal bone differs to the resorptive tissue reactions in all socket bone walls after simple extractions. Contrary to the results of this study, the effectiveness of OFE as a means for implant site development has been presented in the form of case reports with a general consensus that the method can result in favourable hard and soft tissue regeneration and can serve as a unique treatment option for implant site development in highly demanding cases regarding aesthetics[25]. Nevertheless, the validity of the existing case reports could be questioned as bone response either was not rigorously evaluated or was based on twodimensional intraoral radiographs, which hinder the appropriate visualization of the critically important buccal bone. By using CBCT as the assessment method in the present investigation, it was feasible to view and quantify in detail any changes in alveolar socket hard tissues. A positive association was seen between the reduction of buccal alveolar height in the central socket areas with both the buccal and palatal root length meaning that the greater the root length the more pronounced the reduction of buccal bone was due to treatment. In addition, negative association was noted between buccal bone loss in the central socket areas and baseline thickness in the apical level showing that the thicker the alveolar plate was at the apex the less bone reduction was observed.

V. CONCLUSION

OFE resulted in favourable increase in the heights of the palatal and proximal alveolar bone and significant reduction in the buccal plate height, which inhibited implant placement in 35% of the treated sockets. The results of this study generally apply when extrusive forces are delivered at a distance from the CR of treated teeth using conventional fixed orthodontic appliances and the straight-wire technique. Future studies may focus on the standardization of CBCT measurements and the development of more favourable orthodontic biomechanical systems. In this context, ideal force systems regarding force magnitude and direction could achieve orthodontic extrusion without putting the burden of pressure on the thin buccal alveolar plate. Consequently, favourable tissue remodelling and implant site development could be generated through orthodontic bioengineering and elimination of extensive surgical procedures for alveolar reconstruction.

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