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Three-dimensional digital planning of class III decompensation with clear aligners: Hard and soft tissue augmentation with concomitant corticotomy to stretch the limits of safe orthodontic treatment

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ABSTRACT

Purpose: Three-dimensional diagnosis has shown that orthodontic therapy could potentially move the roots of the teeth outside the original bone structure. The purpose of these case studies was to test the possibility of obtaining correct three-dimensional tooth positioning with clear aligners, thereby modifying the periodontal structure accordingly, at the same time.

Methods: Regenerative Corticotomy (RC) was performed with clear aligners on ten adult patients (40 anterior teeth) with skeletal Class III malocclusion, for dental decompensation, prior to the orthognathic surgery. The CBCT examinations were performed before treatment (T0) and 1 year after orthognathic surgery (T1). The vertical and the horizontal hard tissue changes, the width of keratinized gingiva, the incisors proclination (IMPA) and the percentage of inclination compared to the planning were analyzed.

Results: The distance between the Cemento-Enamel Junction (CEJ) and the Bone Marginal Level (BML) decreased in average from 5.5 ± 3.2 mm to 1.39 ± 0.53 mm. The horizontal changes were at the 3 mm level 1.42 ± 0.5 mm, at the 5 mm level 1.98 ± 0.66 mm and at the 7 mm level 2.70 ± 0.87 mm. The width of Keratinized gingiva changes were on average 1.42 ± 0.36 at T0 and 4.16 ± 2.25 at T1. All the changes were statistically significant with $p < 0,05$. The mean proclination based on IMPA values was +9.16 +-1.19°. The mean difference of the incisor's proclination compared to the digitally planned was −1 +-0.6° (89.87 +- 6.46%).

Conclusion: Clear Aligners with three-dimensional digital planning seems to be reliable in controlling teeth movements in the pre-orthognathic decompensation phase. Regenerative Corticotomy seems to have the ability to improve the periodontal tissues despite proclination.

1. Introduction

Three-dimensional diagnosis demonstrates that orthodontic therapy can potentially move the roots of the teeth outside the original bony structure.[1] This may lead to several periodontal problems. Three-dimensional digital planning may help to foresee such possible movements. The cases whose objective of the orthodontic treatment is the skeletal Class III orthognathic decompensation, may displace the roots outside the original bony structure. This means that periodontal side effects, like resorption of the buccal plate and/or the thinning of the overlying gingiva, are highly probable.[2] Furthermore, a higher risk of gingival recession may occur and the presence of a rapid progression of periodontal disease in susceptible patients several years after completion of the treatment could be an eventuality.[3] Studies have shown that Regenerative Corticotomy (RC) (also known as: PAOO®, Periodontally Accelerated Osteogenic Orthodontics) can counteract the marginal bone resorption due to root movement outside the bony structure, both in conventional treatment[4,5] and in orthognathic cases.[6]

Authors have not focused on Clear Aligners (CA) nor on the associated effect of RC on soft tissue reactions. Ahn and colleagues, in 2016,[7]

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Table 1
Analysis of all the proclination of the lower incisors, in 10 cases, in each tooth, as decompensation of the Class III, programmed by the orthodontist and performed during the orthodontic treatment of preparation for maxillofacial surgery.

Patient	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9	Case10
IMPA T0 (°)	80,3	78,7	76,9	77	80.5	78.3	77.9	79.4	78.9	80.1
IMPA T1 (°)	87,5	87,7	88,1	84.3	89.6	88.2	87.3	89	88.7	89.2
Difference between the IMPA T1 and IMPA T0 (°)	(+7,2)	(+9)	(+11,2)	+7.3	+9.1	+9.9	+9.4	+9.6	+9.8	+9.1
Planned Proclination	+9.7	+9.2	12	8.3	+9.5	11	+10.8	+10.5	+10.7	+9.9
Difference between the planned and the obtained Proclination (°)	−2,5	−0,2	−0,8	−1	−0.4	−1.1	−1.4	−0.9	−0.9	−0.8
Difference between the programmed and the obtained of Proclination (%)	74.22	97.8	93.3	87.9	95.8	90	87	91.4	91.6	91.9

Legend: IMPA: angle between mandibular plane and inclination of lower incisors on lateral teleradiography.

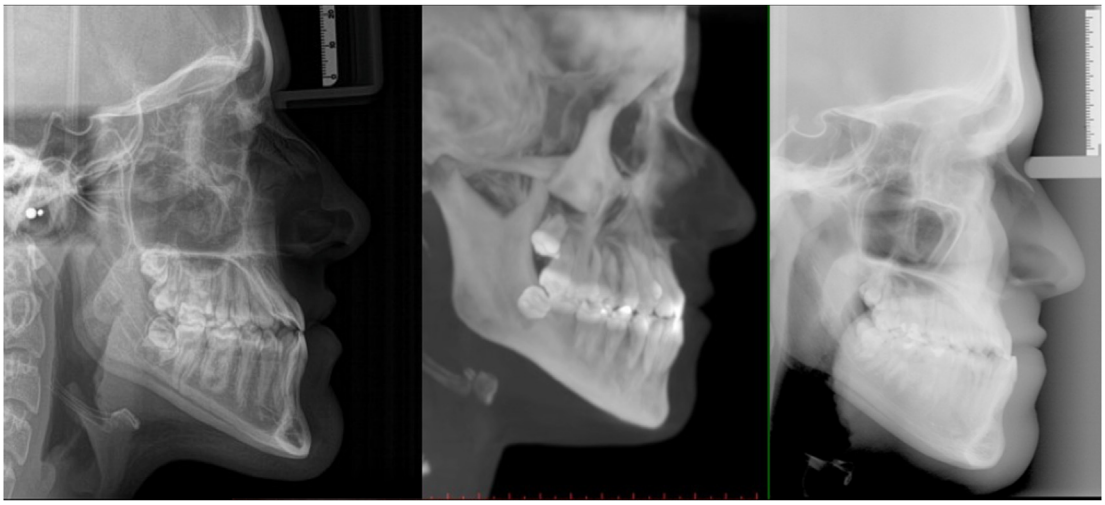

Fig. 1. Pre-operative cephalometric showing a class III skeletal discrepancy.

evaluated two groups of 15 patients undergoing Class III orthognathic correction. The decompensation was associated with Augmentation Corticotomy only in the Test group, resulting in a preservation or augmentation of the periodontal structures after the decompensation. This complies with the application of Augmented Corticotomy in orthodontic treatment in non-surgical cases.[8] Many studies have involved patients treated with brackets and wires. CA is a viable alternative to brackets and wires to correct many different malocclusions. Various authors have questioned the ability of CA in controlling tooth movement,[9] while others have found the effectiveness of CA and braces to be similar.[10] However, CA is advantageous in giving superior aesthetics, greater comfort and an easier oral hygiene.[11] The majority of the studies involving a comparative group, has significantly older patients in the group treated with Invisalign®,[12] this has resulted in the alteration of

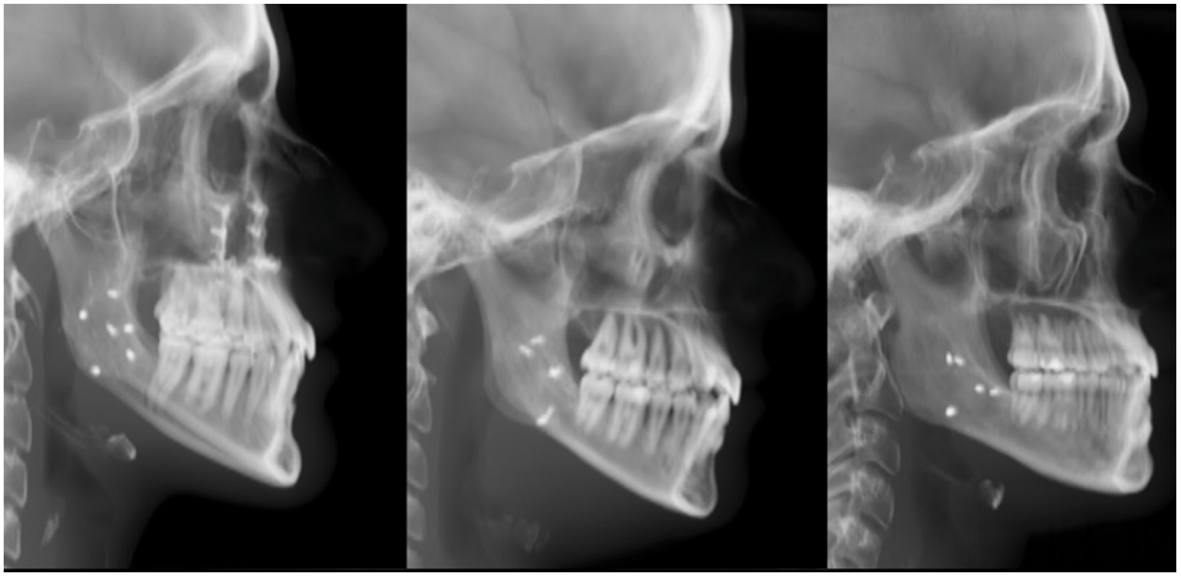

Fig. 2. Post-operative cephalometric showing surgical correction of the skeletal class III discrepancy.

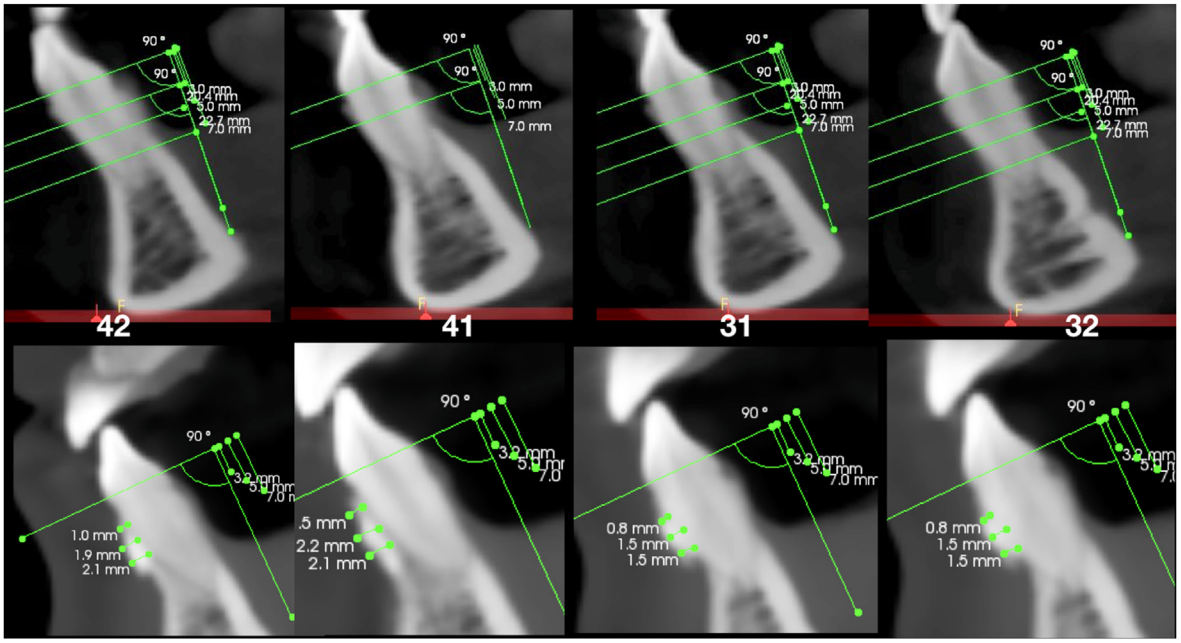

Fig. 3. Pre- and post-operative measurements on CBCT sections. Thickness of the buccal plate were measured at 3 different level (3, 5 and 7 mm from CEJ) and compared. See Table 2 for Results.

movement accuracy and treatment time. With the 3-D design software, CA allows the planning of individual tooth movement or of groups of teeth.

2. Material and methods

2.1. Clinical examination and diagnosis

Ten consecutive healthy (ASA 1) patients (7 females and 3 males, between the ages of 17–19, average 18,3y) were treated. The intraoral examination revealed no periodontal problems, no active carious lesions and no TMJ problems. The extraoral examination showed a prognathic profile with lip incompetence at rest. All the patients had dental and skeletal Class III malocclusion with moderate crowding in both dental arches, negative overjet and the protrusion of the upper incisors and the retrusion of the lower incisors (dental compensation). The cephalometric analysis at T0 indicated a skeletal Class III and a hyperdivergent pattern of the vertical dimension, the proclination of the upper incisors and the lingualization of the lower incisors (Table 1). Three-dimensional radiographic examinations with CBCT were taken before treatment (T0) (Fig. 1) and a year after the orthognathic surgery (T1) (Fig. 2). From this analysis, the lingual or labial inclinations for each individual tooth/root were evaluated by using the axial slices perpendicular to its long axis. The image slices, perpendicular to the axial ones, were automatically reconstructed. This results in optimal visualization of the Marginal Bone Level (MBL) in relation to the Cemento-Enamel Junction (CEJ) in axial, coronal, and sagittal views, as described by Lund.[1] All the cases underwent a pre-orthognathic orthodontic treatment phase in order to correct dental compensation of the skeletal discrepancy. The patients were informed of the procedure and they or their parents, signed a consent form. Three-dimensional digital planning was performed with a dedicated software (ClinCheck®, Align Technology). The treatment was carried out with CA (Invisalign®, Align Technology). The RC (PAOO®) was performed 2–4 weeks into the orthodontic treatment, so as to regenerate bone in the direction of the dental movement, reducing the risks of long-term periodontal defects. The procedures and the materials used were conventional. The Code of Ethics of the World Medical Association (Declaration of Helsinki) was respected as was the approval by the ethical board of the Hospital.

2.2. Three-dimensional digital planning

Intra-oral scanning was performed (iTero® Element 1, Align Technology). The Digital treatment planning included decompensation, in preparation for the surgery. The software enables individual tooth movement, thereby, giving a more precise control of the movements throughout the treatment[13] (Table 1).

2.3. Regenerative Corticotomy

Shortly after starting the orthodontic treatment, augmentation corticotomy was performed. The surgery was carried out during aligner number 2 and 4 in the lower canine to canine area. A new tunnel approach facilitated the post-surgical recovery[14] by performing a few small vertical incisions. Following corticotomy an acellular dermal collagen matrix of animal origin (Mucoderm ® -Botiss Biomaterials Zossen, Germany) was trimmed to allow sub-periosteal insertion. A xenograft was placed underneath the membrane once it was secured. The intra and the extra-oral photography and the CBCT were recorded at 1 year. No complications or adverse reactions were recorded.

3. Results

3.1. Radiographic evaluation

CBCT examinations were performed before starting the orthodontic treatment and at the end of the treatment. All the examinations were made using a 9000 3D CBCT (Carestream Health, USA) unit, equipped with a flat-panel detector. The exposed volume was 50 mm by 30 mm (voxel size = 0.679 μ to 0.2 mm, depending if a "stitching" of 3 consecutive volumes was performed to represent the entire jaw), encompassing the teeth in the jaw where corticotomy was carried out. Exposure parameters were: 70 kV, 8–10 mA (based on the subject's size), and a single 360° 24–72 s exposure time comprising a range of 235–468 projections. CBCT were performed to evaluate the thickness of bone and the 3D positioning of the roots in the alveolar ridge before treatment. Primary data reconstructions were made using the acquisition software (CS3D Imaging, Carestream Health, USA), resulting in perpendicular slices in axial, coronal, and sagittal planes of the image volume.

Table 2
Buccal plate thickness at 3, 5 and 7 mm from CEJ (Cemento-Enamel Junction).

	Number of teeth (n)	Average Thickness	Standard Deviation
Horizontal 3 mm			
Pre op	40	0.19	0.30
Post op	40	1.65	0.60
Horizontal 5 mm			
Pre op	40	0.29	0.42
Post op	40	2.42	0.83
Horizontal 7 mm			
Pre op	40	0.40	0.60
Post op	40	3.11	1.14

Difference are statistically significant $p < 0.05$.

Subsequently, a second reconstruction was made to obtain contiguous 0.5 mm thick slices.

The thickness of the buccal plate was evaluated at 3-5-7 mm from the CEJ on CBCT at T0 and T1 (the difference statistically significant $P < 0.05$) (Fig. 3). The mean difference was at the 3 mm level 1.42 ± 0.5 mm, at the 5 mm 1.98 ± 0.66 mm and at the 7 mm 2.70 ± 0.87 mm (Table 2). The distance between the CEJ and BM was also evaluated, and a decrease of an average of 5.5 ± 3.2 mm at T0 to 1.39 ± 0.53 mm at T1 was recorded (the difference statistically significant (<0.05) (Fig. 4). The changes were statistically significant with $P < 0.05$ (Table 3). The mean proclination based on IMPA values was +9.16 +-1.19°. *No signs of apical resorptions were noticed.*

3.2. Soft tissue evaluation

The changes of the keratinized gingiva were evaluated comparing the intraoral pictures. The measurements were taken with an open source image-processing program (J Image, https://imagej.net/). The width measurements of the central upper right incisor form the STL file of each patient was recorded and used to calibrate the values (Fig. 5). The measurements were calculated at T0 and T1 slides for each single tooth. The keratinized gingiva width averaged 1.42 ± 0.36 mm at T0 and 4.16 ± 2.25 mm at T1 (statistically significant with $P < 0.05$) (Table 4).

3.3. Proclination values

The proclination of the incisors after decompensation was compared to the values that were digitally programmed by the software. The mean proclination of the incisors compared to the digitally planned was - 1 +-0.6° (89.87 +-6.46%).

4. Discussion

Gingival recession in orthodontic treatment is a growing concern.[15] A higher incidence of gingival recession in patients treated for transverse discrepancy has been observed,[16] authors have failed to correlate the two.[17] One hypothesis is that orthodontics may create marginal bone resorption thereby, weakening the anatomical site which may require time to develop a recession.[18] Recessions are twelve times more likely to occur when more than 5 mm of crowding are present,.[19] A recent study[20] states that six years after treatment, the recession of the lower incisors is 8 times more likely to occur. Time and an inflammatory process may be necessary for soft tissue migration and gingival recession. It was retained that any expansive movement may cause bony dehiscence and eventually gingival recession.[21] Many studies have used two-dimensional radiography, restricting the safe expansive movement to proximal bone surfaces.[22] Recently, 3D radiographic analysis shows that Orthodontic movement may inadvertently reposition the teeth beyond the bony

Table 3
Bone vertical height. Distance from CEJ (Cemento-Enamel Junction) to marginal bone level (MBL).

Vertical (CEJ MBL)	Number of teeth (n)	Average distance	Standard Deviation
Pre op	40	5.40	3.20
Post op	40	1.39	1.14

Difference are statistically significant with $p < 0.05$.

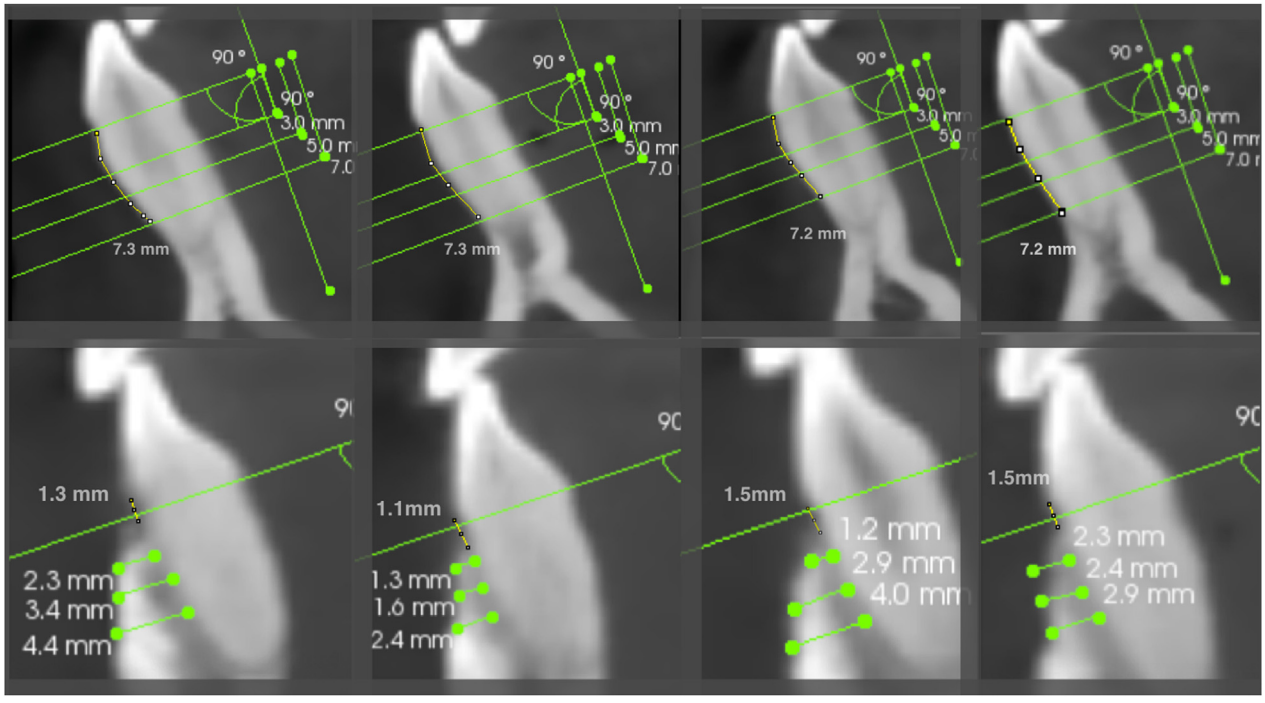

Fig. 4. Pre- and post-operative measurements on CBCT sections. Distance from Cemento-Enamel Junction (CEJ) to Marginal Bone Level (BML) were compared. See Table 2 for Results.

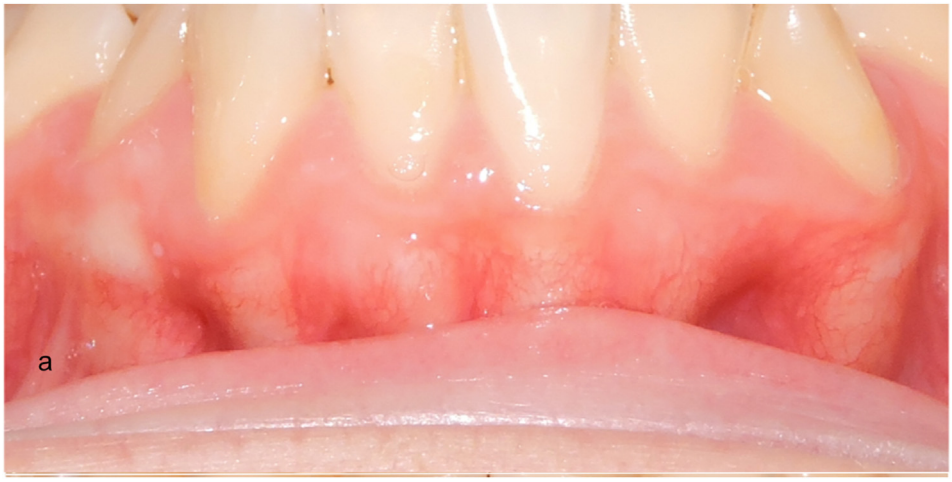

Fig. 5a. Pre-operative view of soft tissue in the anterior inferior area (incisors).

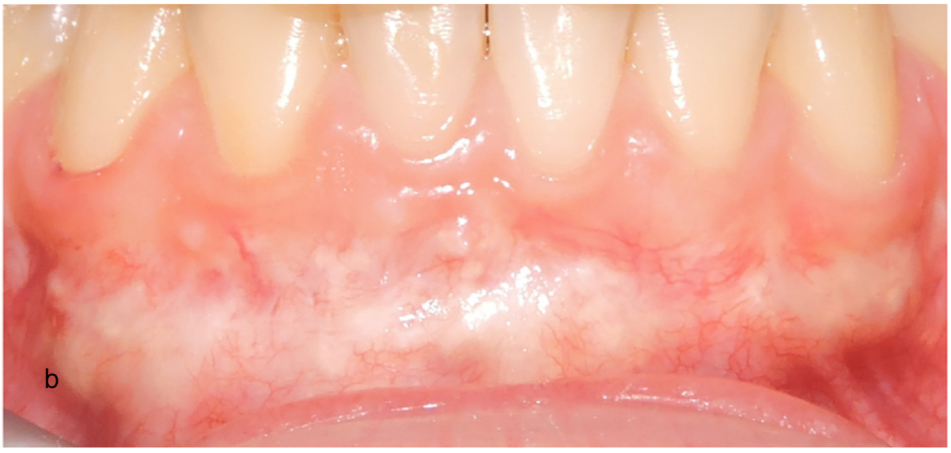

Fig. 5b. Post-operative View of the same area. Note augmentation of Keratinized tissue.

Table 4
Width of Keratinized Gingiva in mm.

Keratinized Gingiva	Number of teeth (n)	Average Thickness	Standard Deviation
Pre op	40	1.4	0.56
Post op	40	4.16	2.25

Difference are statistically significant with P 0.00 $p < 0.05$.

alveolar housing. This may create bone dehiscences and fenestrations.[23] The correlation between rapid palatal expansion and the thinning of the buccal bone was also demonstrated.[24]

PAOO® may help to modify the alveolar anatomy following the position of the roots.[25] Orthodontic treatment should aim to three-dimensionally position the roots inside the bony envelope at the end of the treatment.[26] The combination of corticotomy and a regenerative procedure has the ability to augment the original anatomy despite unfavorable root movement.[27,28] A very recent Best Evidence Review of the American Academy of Periodontology confirmed that bone grafting and corticotomy, together with perfectly planned orthodontic treatment, may provide clinical benefits such as modifying periodontal phenotype, maintaining or enhancing buccal bone thickness, accelerating tooth movement, expanding the scope of safe tooth movement for patients undergoing orthodontic tooth movement.[29] In a retrospective analysis, this only happened when a bone regenerative procedure was combined with corticotomy. Whenever corticotomy was performed alone, the preservation of the existing bone volume was rarely achieved.[8] Despite the tunnel approach, it was possible to control the positioning of the grafting material and to regenerate bone, even in the most coronal portion of the alveolar bone, which is typically the most critical part. The T1 images of the CBCT in fact show two important findings: 1- the bone graft was precisely positioned at the marginal bone level; 2- the buccal plate massively increased despite the proclination of approximatively 10° compared to the T0 scans, both in thickness and in vertical height. This may clinically translate into more bone structure that correctly accommodates all the teeth within the alveolar bony envelope and therefore, prevents extractions of premolars, which is often contemplated in orthognathic cases.

5. Conclusions

The combination of CA orthodontic technique and RC seems to be an effective method to increase both soft and hard alveolar tissues in decompensation. This may happen despite an unfavorable movement of the roots outside the original bone anatomy. The tunnel approach, if correctly used, does not interfere with precise positioning of the graft. The association of 3-D digital planning and CA allows for an accurate control of the orthodontic movements. The use of the digital dental movements' software generates a treatment plan with details, both in terms of degrees and millimeters, with high orthodontic predictability. The pre-surgical decompensation with bone regeneration in skeletal

Class III may avoid non-reversible treatment such as premolar extractions while lowering the risks of detrimental side effects on the periodontal structures.

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