ANALYSING TREATMENT RESULTS BY SUPERIMPOSITION OF CBCTs

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Abstract: The three-dimensional (3D) imaging is being widely used in all dental fields. In orthodontics one of its uses is for 3D superimposition methods. There are three methods to compare Cone Beam Computed Tomography (CBCT) scans of the same patient taken at different treatment time-points. They are landmark-based, surface-based and voxel-based methods. The superimposition allows us to analyze and compare the dental, skeletal and soft tissue changes during orthodontic treatment. Thus, allowing us to evaluate the efficiency of the treatment method and the effects of the orthodontic appliance. By using landmark-based CBCT superimposition software we aim to create clinical protocol for comparing the transversal (dental, skeletal and soft tissue) changes after using Rapid Maxillary Expansion (RME) in growing patients. Consecutive CBCT scan of the patients were made – one at the beginning of the treatment (at the stage of orthodontic treatment planning) and one after the rapid maxillary expansion had finished. Each of the CBCTs were analyzed and the obtained values and measurements were put in a table by order. The same reference bone points and planes were used. Then the superimposition method was done using the software. This superimposition method relies on localizing the landmarks on stable anatomical structures. The software offers manual placement of the landmarks using fitting tool where the user places 3 landmarks sequentially on the initial and on the final CBCT scan. It starts by placing the first landmark on the final CBCT and finishes with placing the last on the initial CBCT. For better accuracy the software allows adjusting the bone density thresholds for both CBCT scans so that the bone surface can be displayed equally. If there are any mismatches, they can be corrected by manually rotating or moving the final volume. After superimposing the volumes, the dental, skeletal and soft tissues changes can be evaluated by using different measurement tools. The landmark-based method requires knowledge of the anatomical structures and well-trained eye of the user in order to get good superimposition. The used software provides user-friendly and fast superimposition method, allowing the clinicians to perform it easily. The landmark-based method is reliable but less accurate method compared to the surface-based and voxel-based superimposition methods. It gives credible and reproducible results for the purpose of the clinical protocol and the research. The results obtained from the superimpositions are commensurable and corresponding to the difference in the measurements obtained from separate measurements made on the initial and final CBCTs. The CBCT software analysis allows the assessment of the airway volume changes with different orthodontic treatments and appliances. A disadvantage of the software is that it does not allow comparing and superimposing of the segmented jaws taken from the CBCT.
Keywords: CBCT superimposition, 3D imaging, landmark-based method, rapid maxillary expansion, orthodontics.

1. INTRODUCTION

The technological advancement made possible the use of many different software in every stage of the orthodontic planning – diagnosis, treatment planning, design and production of orthodontic appliances, patient file storage, visual plan to forecast the normal growth of the patient – Visual Treatment Objective (VTO). (Yordanova, Gurgurova, et al., 2023)

The superimposition of before- and after-treatment are regular part of the orthodontic analyses. Superimposition of lateral skull radiographs is routinely used and is required in orthodontic examinations around the world. But the two-dimensional (2D) radiographs have several limitations because they are projections of three-dimensional (3D) craniofacial structures, which leads to overlapping of bilateral structures, image distortion and errors in landmark identification.(Dot et al., 2020)

The three-dimensional (3D) imaging in recent years is being widely used in all dental fields. In orthodontics one of its uses is for 3D superimposition techniques. There are three methods for superimposing Cone Beam Computed Tomography (CBCT) scans of the same patient taken at different treatment time-points. They are landmark-based, surface-based and voxel-based methods.

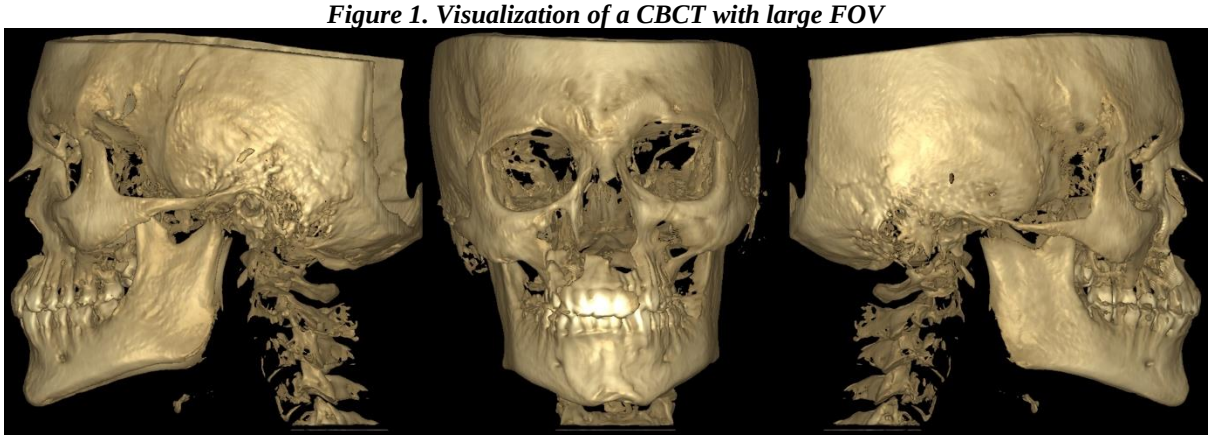
The landmark-based method requires stable anatomic structures.

The surface-based method is also called feature-based 3D superimposition. This method registers high quality 3D surface models of the stable structures. The 3D surface models sometimes can be tedious to obtain and can require scanning protocols with higher exposure to achieve better quality of the CBCT.(Almukhtar et al., 2014)
Voxel-based registration is a method where the gray values in a defined volume of interest are compared to calculate the rotation and translation required to align the initial and final CBCT image data. This is done by using mathematical algorithms based on probability and information theory.(Han et al., n.d.) In previous literature this method was considered to be more accurate than the surface-based method, because it does not depend on the precision of the scanned 3D surface models.(Grauer et al., n.d.)
The superimposition allow us to analyze and compare the dental, skeletal and soft tissue changes during orthodontic treatment with Rapid Maxillary Expansion (RME). Thus, allowing us to evaluate the efficiency of the treatment method and the effects of the orthodontic appliance. Clinical research has shown that there is significant increase in the width of the maxillary arch, the palate in first molar area, the width of suture space and midpalate suture width. There were also statistically significant changes in the structures of the nose and maxillary sinuses – increasement in the nasal width and nasal base width and reduction of the maxillary sinus width.(Vo et al., 2021) The Rapid Maxillary Expansion produces greater expansion in the posterior part of the maxilla than the anterior part.(Rutili et al., n.d.)

2. MATERIALS AND METHODS

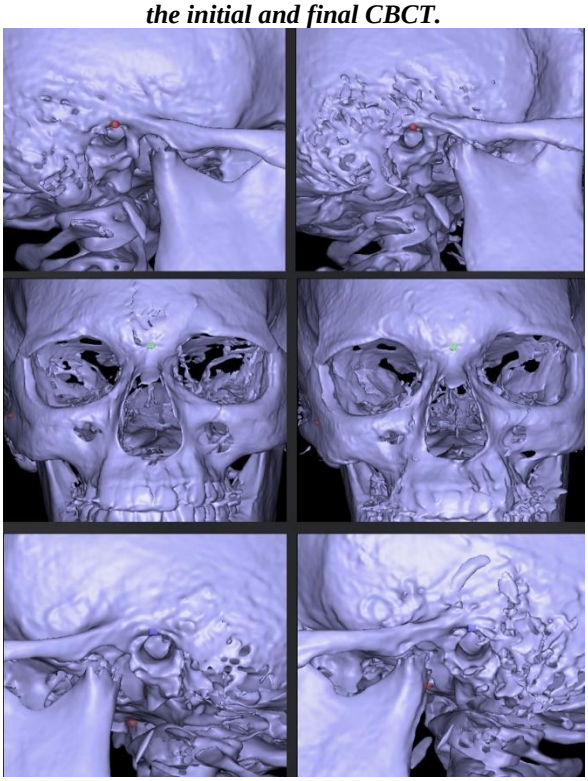
By using landmark-based CBCT superimposition software we aim to create clinical protocol for comparing the transversal (dental, skeletal and soft tissue) changes after using Rapid Maxillary Expansion (RME) in growing patients. The used software is Planmeca Romexis 6.4.4.7 and its 3D imaging Superimpose module. Consecutive CBCT scan of the patient were made – one at the beginning of the treatment (at the stage of orthodontic treatment planning) and one after the rapid maxillary expansion had finished. As a finishing point, we mark the moment after three months of retention period that followed the active expansion. All of the CBCT scans have large Field of view (FOV) – the images include the entire craniofacial skeleton, also enabling us to do 3D cephalometric analysis if needed. (Fig.1)

Figure 1. Visualization of a CBCT with large FOV



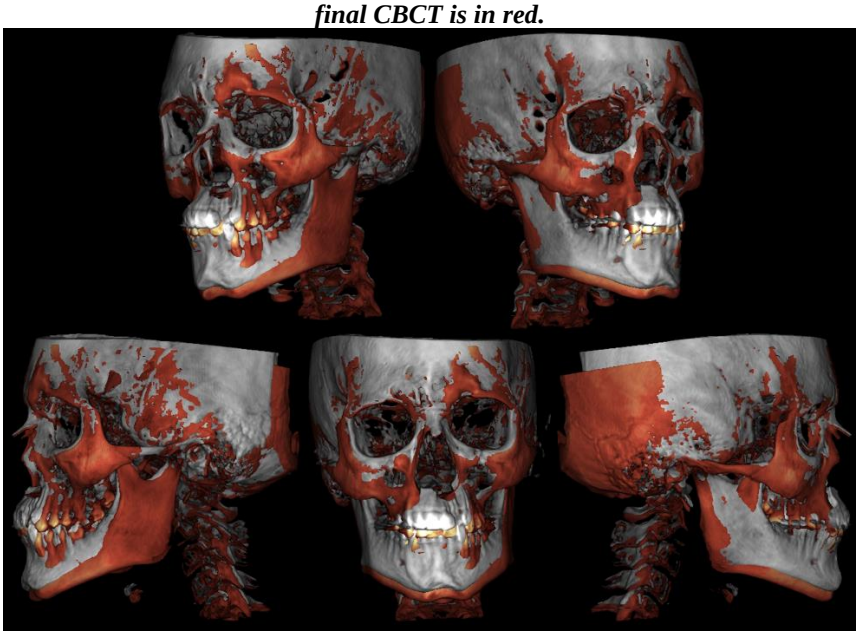
Each of the CBCTs were analyzed and the obtained values and measurements were put in a table by order. They were analyzed using the 3D Ceph module which includes the Total Face Approach (TFA) (used to determine the symmetry in vertical and sagittal planes) and transversal analysis. The same reference bone points and planes were used. Then the superimposition method was done using the software. This superimposition method relies on localizing the landmarks on stable anatomical structures. The software offers manual placement of the landmarks using fitting tool where the user places 3 landmarks sequentially on the initial and on the final CBCT scan. First an import of the initial CBCT is made and then the work continues with the Superimpose module. A “New fitting” window opens and the option “Use Fitting Tool” is chosen. Then a window opens where the fitting is done step by step – import of the after CBCT, then the landmark placing. It starts by placing the first landmark on the final CBCT and finishes with placing the last on the initial CBCT. (Fig.2)

Figure 2. Parallel placement of the 3 landmarks (right and left Porion and Nasion) using the "Fitting tool" on the initial and final CBCT.



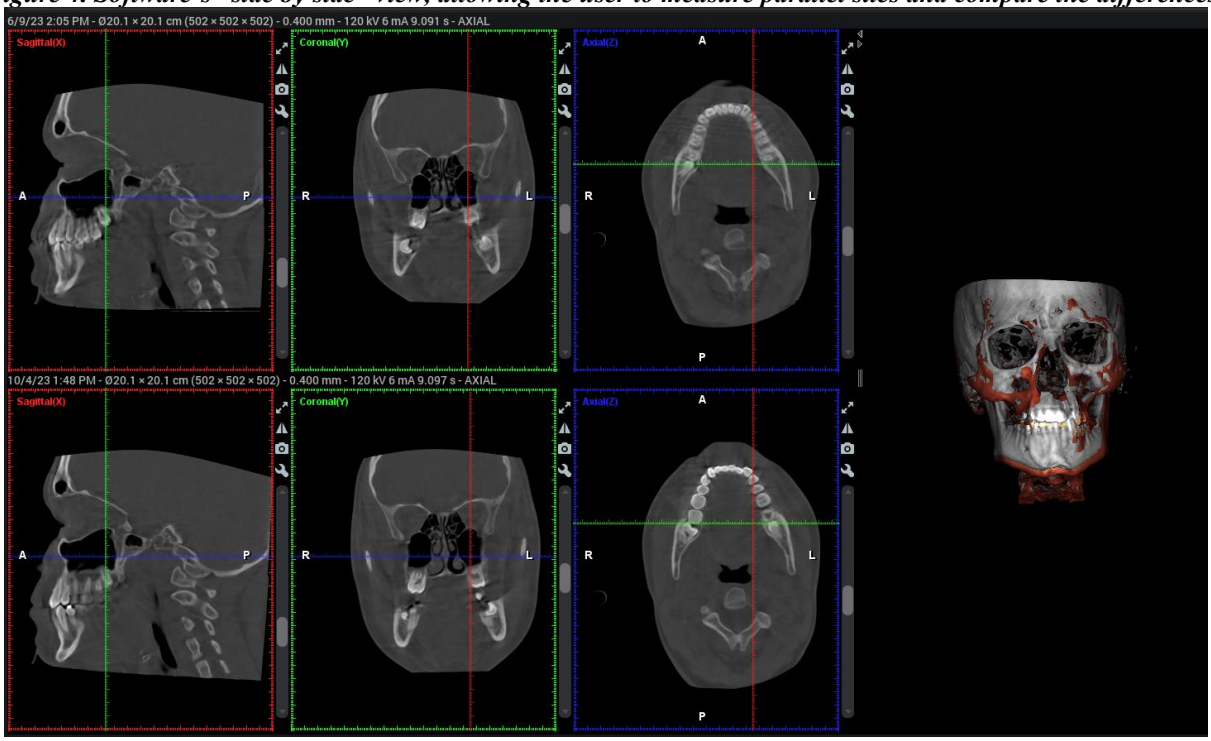
For better accuracy the software allows adjusting the bone density thresholds for both CBCT scans so that the bone surface can be displayed equally. The superimpositions were done using the following skeletal landmarks – right and left Porion (Po) and Nasion (N). They were chosen because, as part of the cranium they are stable and do not change during orthodontic treatment. (Fig.3)

Figure 3. Visualization of 3D superimposition of the initial and final CBCTs. The initial CBCT is in grey, the final CBCT is in red.



If there are any mismatches, they can be corrected by manually rotating or moving the final volume. After superimposing the volumes, the dental, skeletal and soft tissues changes can be evaluated by using different measurement tools in the Annotation section. (Fig.4)

Figure 4. Software's "side by side" view, allowing the user to measure parallel sites and compare the differences.



3. RESULTS

By using the landmark-based method of Planmeca Romexis, the clinical protocol that was created gave accurate superimpositions that needed none or very little adjustments. The landmark-based method requires knowledge of the anatomical structures and well-trained eye of the user in order to get good superimposition. The used software provides user-friendly and fast superimposition method, allowing the clinicians to perform it easily.

4. DISCUSSION

The landmark-based method is reliable but less accurate method compared to the surface-based and voxel-based superimposition methods.(Ghoneima et al., 2017) It gives credible and reproducible results for the purpose of the clinical protocol and the research. The results obtained from the superimpositions are commensurable and corresponding to the difference in the measurements obtained from separate measurements made on the initial and final CBCTs. It enables the user to measure the changes in the three dimensions, to measure the skeletal, dental and soft tissue changes. The CBCT software analysis also allows the assessment of the airway volume changes with different orthodontic treatments and appliances. This method is useful when comparing the airway changes in mouth breathing patients. The use of Rapid Maxillary Expansion is a suitable treatment for mouth breathers, that can produce significant dimensional increase in the nasal cavity and nasopharynx. It also improves the quality of life of mouth-breathing patients.(Namiko Izuka et al., 2015) It decreases nasal resistance and apnea-hypopnea index (AHI) in patients with sleep apnea.(de Julián-López et al., 2023)

The clinical protocol described above is used mainly when superimposing CBCT of patients treated with tooth-borne rapid maxillary expanders. The expanders are digitally designed and made by selective laser sintering (SLS) allowing the clinician to precisely design the position of the jackscrew, the tooth anchorage, giving then high precision and individuality for every clinical case.(Yordanova, Chalyovski, et al., 2023) During the design process different extension hooks for traction of impacted teeth can be added. (Yordanova-Kostova et al., 2023)

The superimpositions can be used to assess the changes occurring from every type of expansion (rapid, slow surgically assisted, miniscrew assisted) and from tooth-borne, tooth-bone-borne and bone-borne expansion

appliances and comparing the difference of the dental, skeletal and soft tissue changes between each group. (Bazargani et al., 2023)

Some of the disadvantages of the software are that it does not allow comparing and superimposing the segmented jaws taken from the large FOV CBCT, nor comparing extracted airway volumes.

5. CONCLUSION

The 3D superimposition is valuable technique that allows comparing and evaluating dental, skeletal and soft tissue changes. There are many software programs on the market using one of the three different superimposing methods. By using the landmark-based method from Planmeca Romexis software and the described clinical protocol accurate, reproducible and reliable results are achieved. The landmark-based method requires knowledge of the anatomical structures and well-trained eye of the user in order to get good superimposition. The used software provides user-friendly and fast superimposition method, allowing the clinicians to perform it easily.

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