

“The Hybrid HIRO”- Conventional HIRO System Integrated with 3D Scanning and Resin Prototyping

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Abstract

Introduction: The prevalence of lingual orthodontics has been increasing among the youth who prefer to undergo treatment with invisible appliances. The HIRO system is the most popular and widely accepted technique for lingual appliance bonding as it is economical. However, the great precision required for this system renders it highly technique sensitive. The final finish of the case depends, to a great extent, upon the accuracy and precision of each step involved in the HIRO system.

Methods: The present technique describes a novel procedure for lingual indirect bonding using HIRO system. The conventional HIRO system has been modified by integrating 3D scanning and rapid prototyping with treatment planning and virtual diagnostic set-up.

Result: This procedure makes the set-up more accurate for a better finish and saves a lot of laboratory time.

Conclusion: The hybrid HIRO is a cost effective method for patients who cannot afford a fully customized lingual appliance. It also opens a range of possibilities for the incorporation of 3D technology in routine clinical practice.

Keywords: 3D Scanning, Resin prototyping, Virtual model, HIRO system.

INTRODUCTION

Over the past two decades, the demographics of patients receiving orthodontic treatment have changed from predominantly children to a marked increase in the number of adults. The prevalence of lingual orthodontics is a promising solution to the increased surge in demand for concealed and indistinct orthodontic appliances.¹ The constant refinement that has been brought in to indirect bonding technique has played a pivotal role in success of lingual orthodontics.² Since the indirect bracket positioning procedure takes the direct bracket positioning control out of the hands of the orthodontist, the difficulty in precise bonding of lingual fixed appliance still persists. The difficulty in access, lack of easy direct visualization and the wide anatomical variation of the lingual surfaces of the teeth, makes indirect bonding an essential requisite for redefining precision in lingual orthodontics.³ Moreover, as the success of lingual mechano-therapy depends upon the position of lingual bracket in the three dimensions of space, it is necessary to take into consideration the constant variables, like the lingual anatomy, the bucco-lingual thickness of teeth and their torque requirements, which determine the need for bracket base customization.⁴ Furthermore, indirect bonding significantly reduces torque error and rotational deviation of brackets during placement.⁵ Among the various laboratory techniques

available for indirect positioning and bonding of lingual brackets, the HIRO system is most commonly used as it is easy to perform, simple and economical.² However, this system is highly technique sensitive and relies on fabrication of an accurate orthodontic set-up upon which the final finish of the lingual orthodontic treatment depends. As the goal of orthodontic treatment is to achieve a functional, esthetic and stable occlusion, all these parameters can only be met if appropriate tip, torque and in and out specifications have been incorporated in the model set-up. This makes the orthodontic set-up procedure the most important step in the indirect bonding HIRO system.

The incorporation of digital technology in dentistry, such as CAD-CAM aided 3D scanning of models, digital image capturing and virtual treatment planning on digital models with 3D printing options using resin prototyping have revolutionized the way how orthodontic set up is done for lingual indirect bonding. The present article describes the integration of these processes to develop a digital virtual model and to evaluate and modify this virtual model for construction of an ideal (nearly) 3D virtual set-up.

MATERIALS AND METHODS

The procedure has been illustrated in a 18-year-old male patient who presented with the chief complaint of spacing in the upper and lower front teeth. Clinical and radiographic examination revealed a skeletal and dental Class-I malocclusion (Fig. I). The laboratory procedures for lingual indirect bonding for this case have been divided into digital and manual procedures.

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Figure I (a,b,c,d and e): 18-year-old male patient with a skeletal and dental Class-I malocclusion and spacing in the upper and lower front teeth and bi-dento-alveolar proclination.

A. Digital Laboratory Procedure

After making polyvinyl siloxane impressions, casts were poured with orthodontic stone and scanned with a 3D extra-oral laser scanner (Intellidenta 3D scanner).

Step 1: Digitalization of Study Models-

The models are scanned first in occlusion and then scanned individually for better occlusal surface details. The images are procured and saved as 3D STL (Standard Triangulation Language) files by CAD software (Exocad software).

Step 2: Segmentation and Working of Models-

The digital STL files thus obtained from scanner are then imported into a designing CAD software (3Shapes, Mastro 3D etc.) which allows the orthodontist to work with these virtual models. Here the virtual digital working models are oriented into occlusion by the CAD software based on the information obtained from scanning the models in occlusion (Fig. II). Following this, the anatomic portion of the scanned model is separated from the artistic portion by a process called as segmentation of the image.

Step 3: Virtual Set Up-

The individual teeth are now virtually moved into the desired position over the virtual model to obtain an ideal digital model Kesling setup.

Step 4: Standardization of the Virtual Set Up-

The adjustments in the alignment, tip and torque can be made by assessing the digital set up on a digital grid which allows for checking the bilateral symmetry of the arches, occlusion and the accuracy of Kesling setup with respect to the 1st order, 2nd order and 3rd order specifications or requirements of the case (Fig. III).

Step 5: Digital Output-

After completion of the digital manipulation of the pretreatment STL file, the final digital Kesling setup 3D images are saved as a new post Kesling set up STL file. This new STL file can be mailed to the orthodontist for final checking of the virtual setup to order any final adjustments or corrections if required. The virtual set up

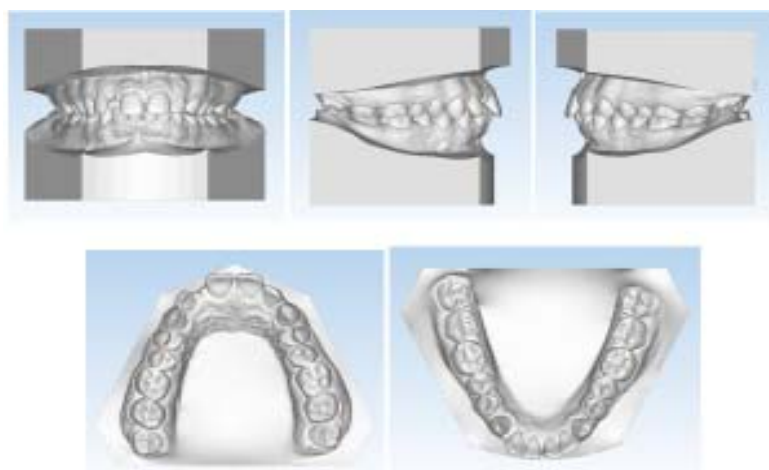


Figure II (a,b,c,d and e): Virtual pre-treatment models oriented in occlusion by information gained by 3D scanning.

can be opened in the STL Viewer software (STL viewer, Maestro 3D viewer, etc) which allows for a three dimensional rotation of the virtual model to view the setup from all planes of space. The orthodontist can check for the occlusion from the lateral as well as lingual views (Fig. IV). Apart from the frontal view of occlusion, the occlusal view is also provided to check for the alignment (Fig. V). All the available views can be superimposed on a virtual geometric grid to check for any minor adjustments required. Zoom and perspective projection are a few among the various options available in the viewer software.

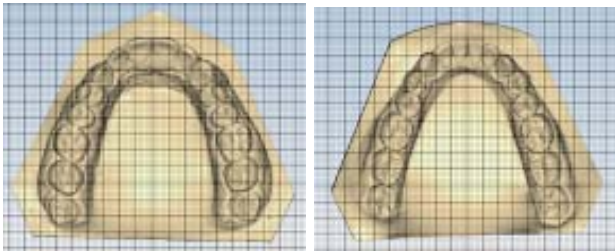


Figure III (a & b)

Checking the virtual set-up on digital grid.

Step 6: 3D Resin Printing-

On confirmation of the setup for its accuracy from an orthodontist, the 3D printing of the virtual setup is commanded. This is done by resin printing at 16 micron layer accuracy with a Poly jet 3D resin printer (Stratasys) which photo cures the resin at each layer during 3D printing⁶ (Fig. VI).

B.Manual Laboratory Procedure

The physical resin models of the ideal virtual set up are later used for fabrication of transfer trays (Fig. VII). First, the resin models are duplicated in orthodontic stone to allow for bonding of brackets (Fig. VIII) or the lingual surface

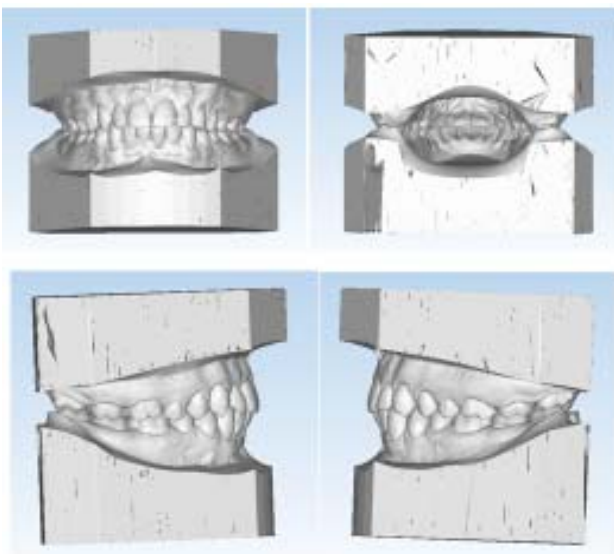


Figure IV (a,b,c and d): Occlusion from frontal, lingual and lateral views.

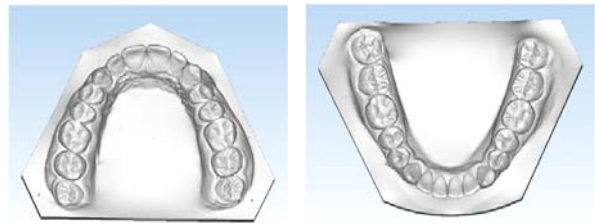


Figure V (a and b): Occlusal view of alignment of the virtual set up.

of the resin model can be micro sandblasted minimally using 25 micron Aluminium oxide sand (360-800 grit) to roughen the surface. From here on, the steps are similar to that of the original HIRO technique.² An ideal mushroom archwire template is made using the same width as the slot of the brackets i.e. 0.018" X 0.025" (Fig. IX) on the duplicated models. The brackets used here are STB brackets supplied by Ormco.*This mushroom archwire must follow the lingual archform as closely as possible and should be free from any torque (Fig. X).

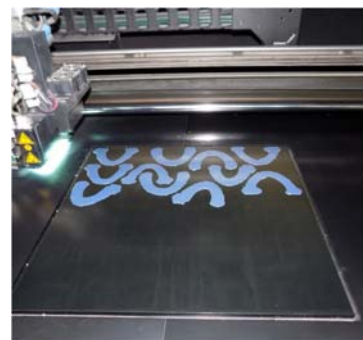


Figure VI: 3D printing using Poly jet 3D resin printer.

The mushroom archwire is stabilized onto the cast to aid as a reference for bonding and if required, for re-bonding (Fig. XI). This stabilized mushroom archwire is used for transferring the information from the set-up to the brackets by bonding the brackets on the master cast with light cure composite resin, Transbond-XT** (Fig. XII).



Figure VII (a,b,c,d and e): Physical resin models of the ideal virtual set up.



Figure VIII (a and b): Ideal setup models duplicated in orthodontic stone.

Later on, the transfer trays are fabricated using cold cure acrylic or soft thermoplastic sheets which are heat softened and adapted to the master cast with brackets to act as transfer trays. These trays are trimmed and numbered for individual teeth and the brackets are ready to be transferred into the patients mouth. The rigid nature of cold cure trays allows precise transfer of brackets with built in information to the patients mouth (Fig. XIII).



Figure IX (a and b): An ideal mushroom archwire template made in 0.018" X 0.025" stainless steel.



Figure X: Checking for torque in mushroom template.



Figure XI: Stabilized mushroom template.

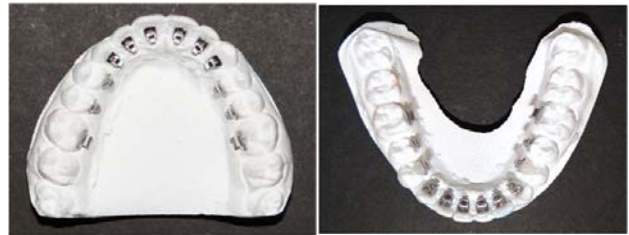


Figure XII (a and b): Bonding of brackets on the models to transfer information from the master mushroom archwire to the bracket base.



Figure XIII (a and b): Brackets bonded in the patients mouth using rigid cold cure transfer trays.

DISCUSSION

Computer technology has begun to influence lingual orthodontics by improving the accuracy and minor details rather than being dependent on human hands and eyes. With the availability of 3D

While considering the customization of 2D lingual brackets using laboratory setup, it is critical to assess the reliability of the virtual setup and the accuracy of the position of teeth in all the planes of space. Here is an attempt to describe the various aspects one by one.

The first order accuracy can be assessed by two methods. One is by co-ordinating the curvature of the pre-treatment model and the master setup. This is done by digitally measuring and comparing the inter-canine and inter-molar width in both the models. The second method is to superimpose the occlusal view of the master virtual setup on a virtual grid and measure the individual crown prominence relative to the embrasure line as originally described by Andrews.⁷ The crown prominence is then compared bilaterally over the grid to check for symmetry (Fig. XIV).

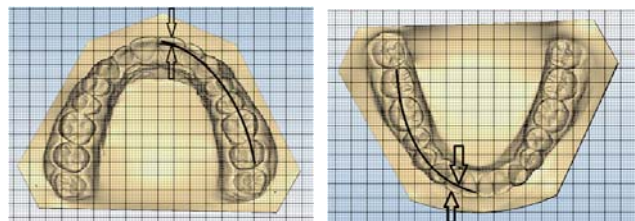


Figure XIV (a and b): First order accuracy is assessed by measuring the individual crown prominence relative to the embrasure lines.

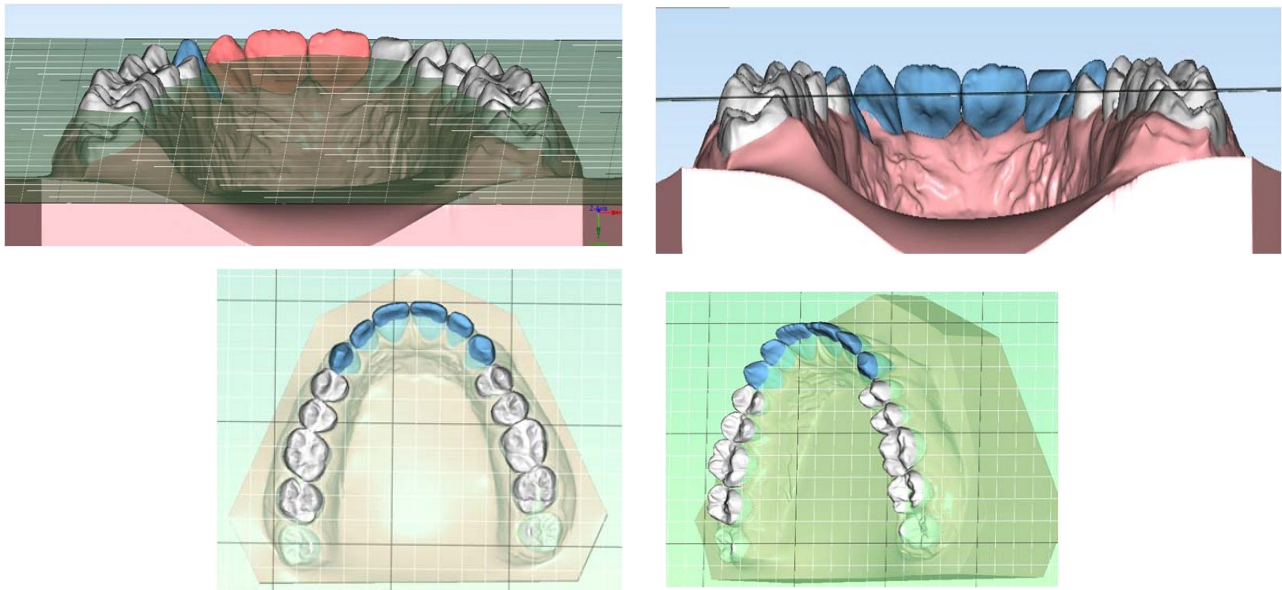


Figure XV (a,b,c and d): Lingual Andrews Plane(LAP) in the maxilla from rear view, occlusal view and angular view.

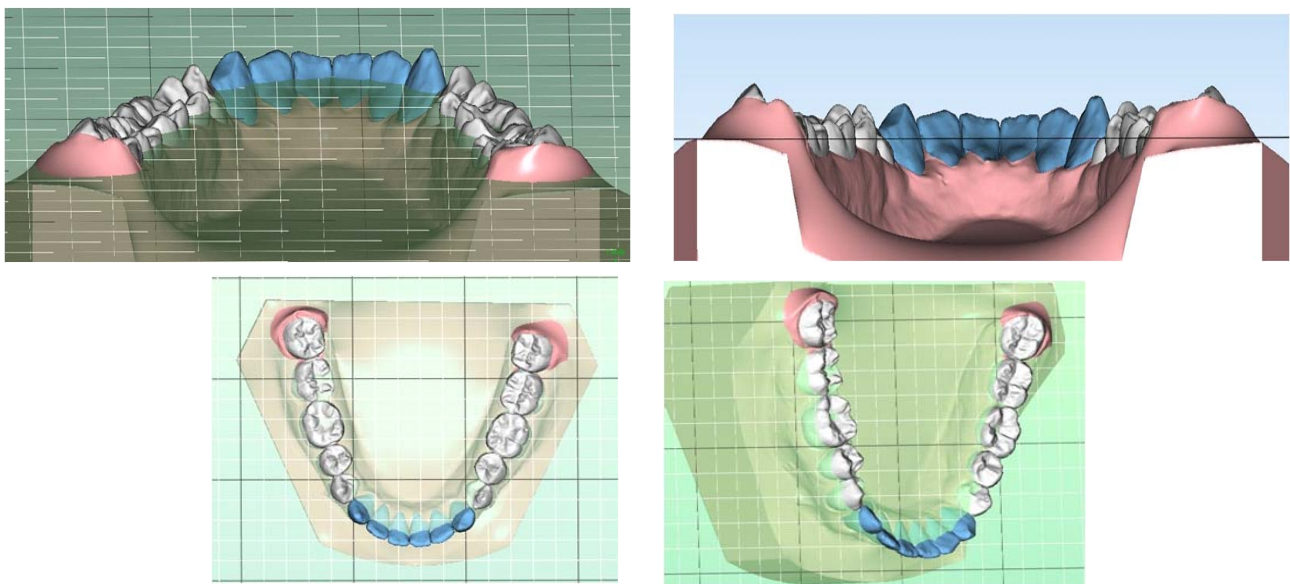


Figure XVI (a,b,c and d): Lingual Andrews Plane(LAP) in the mandible from rear view, occlusal view and angular view.

The second order corrections can be checked by constructing a plane analogous to the 'Andrews plane'. This plane is a surface on which the mid-transverse plane of every crown in an arch will fall when teeth are optimally positioned.⁷ In other words it can be an extension of Andrews plane on to lingual surface of the teeth. It may therefore be termed as the *Lingual Andrews Plane* (LAP) for the ease of communication. The LAP when viewed from the lingual aspect represents the anatomic center of the clinical crown from the lingual aspect and hence dictates the position of the slot of the bracket (Fig.XV, XVI). Since the distance of the incisal or occlusal edges of teeth from the LAP can be measured and compared bilaterally, the second order corrections can be taken care of accurately.

The third order corrections cater to the torque needs of the particular case, and hence should be clearly noted in the treatment planning phase. From the knowledge of lingual biomechanics, it is known that some amount of torque loss is inevitable during the retraction phase in lingual orthodontics⁸. To counteract torque loss, one has to either build more torque in the wire, or increase the torque in the master virtual setup and replicate it in the composite base-build-up of the bracket. The second option is more relevant and less technique sensitive compared to the first one, which is cumbersome and induces reproducibility errors. Therefore, when retraction mechanics is planned, either in extraction cases or in cases with large spacing in the anterior region (as in the given case), extra torque is build



Figure XVII : Extra torque is build up in the master setup to compensate for the future torque loss.

up in the master setup to compensate for the future torque loss (Fig. XVII).

Occlusion has been regarded as the major factor for stability of orthodontic treatment from a very long time⁹. There are another two aspects in the software which allows for further refinement of the setup to achieve a more accurate finishing of occlusion and hence a better stability of the treatment results. First is the provision to check for occlusal contact points which allows the clinician to ensure a proper cusp-to-fosse relationship instead of a cusp-to-cusp relation and to check for any occlusal pre-maturities and correct them in the final set up. The occlusal contact points are represented as areas of greater stress as seen on the occlusal view on the software (Fig. XVIII). The second provision is to check for occlusion in vertical sections as seen on a y-z plane (sagittal), x-z plane and x-y plane (antero-posterior) on a virtual graph (Fig.XIX). These two procedures make it easier for the operator to understand the final occlusal status of the setup prior to physical printing of models. Once the operator and the orthodontist are fully satisfied with the virtual arrangement of the teeth in the ideal

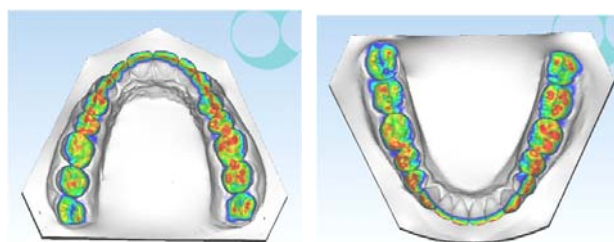


Figure XVIII (a,b and c): Occlusal contact points represented as areas of greater stress as seen on the occlusal view in maxilla and mandible.

master set-up, the models are 3D-printed and further laboratory procedures are carried out.

This technique brings the virtual set-up as close to ideal as possible by allowing for minor corrections in all three planes of space.

The major advantage of this technique is the precision of the setup as it does not depend on the visual perceptions and hands of the operator. Teeth are positioned precisely on the virtual graph mounted on the model which allows to check for first, second and third order placement of teeth. The second major advantage is a plaster free laboratory Kesling set up work. The accuracy is also remarkably improved by eliminating the laboratory steps and, therefore, the chances of errors in them. Another advantage is that the patient can visualize the final result which helps the patient to choose the treatment plan as per their wish. It acts as an excellent patient encouragement and education tool. Lastly, it is also a cost effective method for patients who cannot afford a fully customized appliance.

There are also a few shortcomings of this technique, the major one being the inability of making changes in the

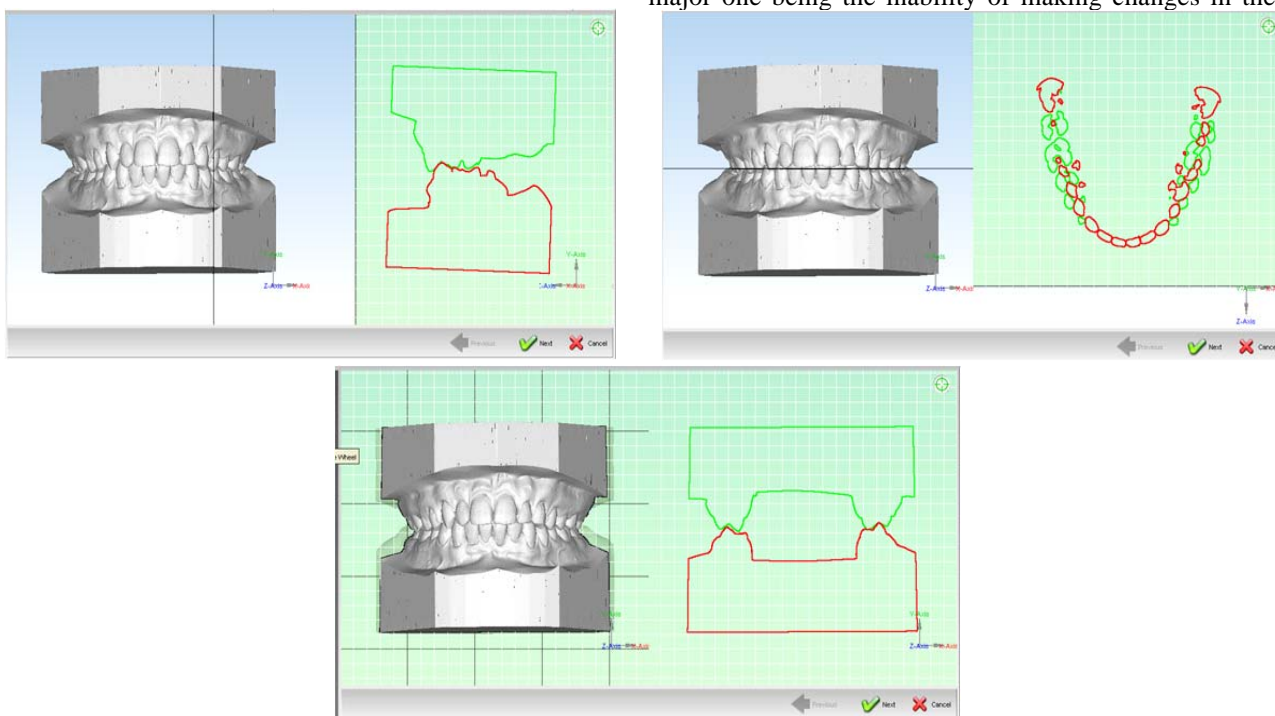


Figure XIX: Checking for occlusion in vertical sections as seen on a y-z plane (sagittal), x-z plane and x-y plane (antero-posterior) on a virtual graph.

setup once the models have been resin prototyped, the only option being to cut the resin model and do the necessary corrections required. Once the treatment goals have been determined at the outset, any treatment plan changes, as can occasionally occur due to either patient request or adverse clinical outcomes, will not be possible.

FURTHER SCOPE

Adding information from a CT scan to the 3D scan while constructing the virtual model would yield more accurate results as the information regarding the root positions from the CBCT scan can aid in achieving a more stable occlusion.¹⁰ Since most CT images taken for diagnostic purpose are of 2mm slice thickness, reproducibility of the surface details and the root surface becomes difficult during 3D reconstruction, hence the slices taken at a distance of 1 to 1.25 mm will make the details much more clear, but with the disadvantage of making the DICOM files more bulkier.^{11,12}

Likewise, transfer jigs can be designed on the virtual model for a given slot size using CAD-CAM technology and can be resin printed to transfer the brackets into the patients' mouth. This would further reduce the laboratory procedure. Another technological advance in this field is the bracket positioning robot which uses highly accurate 3D scanning device to create a virtual setup, onto which the brackets can be placed with high degree of accuracy.

CONCLUSION

Computer technology has advanced over years to allow extremely accurate 3D simulation and treatment planning using 3D scanning and the CAD softwares. The CAD/CAM assisted technology helps in the creation of virtual model, and even the construction of transfer trays to improve the efficiency and the final outcome of lingual treatment mechanics.

These breakthroughs in lingual laboratory procedures not only aid in delivering excellent treatment outcomes but also help in, reducing many of the possible inaccuracies that occur with the creation of an ideal diagnostic set-up on plaster model, and reduce the laboratory time. It is important to emphasize that diagnosis and establishment of an individualized treatment plan is of paramount importance to achieve satisfactory treatment outcome.

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