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A Method For Volumetric Evaluation of Post-Extraction Site's Alveolar Bone Change In Human Subjects.

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Abstract:
Background:*Tooth extraction is one of the most common procedures in the dental practice. The treatment of the extraction site is a daily challenge, which influences the post-extraction bone resorption.*
Purpose:*The purpose of the current short communication is to showcase a novel methodology for volumetric evaluation of bone resorption after tooth extraction.*
Materials and Methods: *In order to present the proposed methodology a plaster cast from a silicon mold is prepared. The upper first molar is trimmed simulating a fresh extraction site. A 3D scan is performed with the Trios intraoral scanner and a virtual study model is generated. A second trimming procedure is performed in order to simulate bone resorption and a second model is digitized. The volumetric change of the bone in the post-extraction site is assessed via superimposition of 3d models. The resulting stereolithography models are imported in suitable software. An alignment procedure is performed with the "best fit" algorithm. After scaling, Hausdorff distance and volume of the differences between the models are measured. A color map and histogram are generated for visualization purposes.*
Results:*The results obtained from stereolithographic models processed with appropriate software make it possible to make a very accurate assessment of linear and volumetric bone changes preoperatively and postoperatively.*
Conclusion:*The proposed method might become a very useful tool for assessing postoperative bone resorption. It is necessary to evaluate the proposed methodology in a clinical setting.*
Keywords:*bone resorption, 3D scan, bone volume, Hausdorff distance*

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I. Introduction

The alveolar bone is a tooth dependent tissue, therefore after tooth removal, severe dimensional changes occur.[1] Tooth extraction is one of the most common dental procedures. Generally, the extraction socket heals uneventfully; even so, the alveolar defect that results is only partially restored. Simultaneously with the bone growth into the socket, there is a resorption of the alveolar ridges. The greatest amount of bone loss is in the horizontal dimension, but a vertical change is also present, mainly in the buccal aspect. [2-4] Although the aforementioned changes are observed and documented no sound method for evaluation of the volume change in the extraction sites is found in the available literature. Researchers rely on two main evaluation techniques - radiographic and clinical, but only linear measurements are taken.[5] Furthermore, due to technical and human limitations, these methods are prone to error.

II. Purpose

The purpose of the current short communication is to showcase a novel methodology for volumetric evaluation of bone resorption after tooth extraction.

III. Materials and Methods

A dental cast from a study silicone mold of the upper jaw is poured from dental stone (Hard Rock, 5th Grade). In order to simulate a fresh extraction site, the first maxillary molar, as well as a portion of the adjacent structures, are removed with a stainless steel bur. A 3 - dimensional virtual model is generated with the Trios(3Shape) intraoral scanner. The option chosen from the software is "study model" since it doesn't require a scan of both arches and a bite registration for the process of sending the 3D model to the 3shape dental system. In the order processing utility, a model for 3D printing is chosen, which outputs an STL file. A second trimming procedure is performed, further reducing the dimensions of the "extraction area" in order to simulate bone atrophy, after a healing period. The same steps are performed for digitization of the altered plaster cast. The STL models are then imported to Meshlab for processing. [6] A semi-automatic alignment procedure is performed with the "best-fit" and "ICP" algorithms. The teeth adjacent to the defect are used as reference points for the virtual model superimposition.

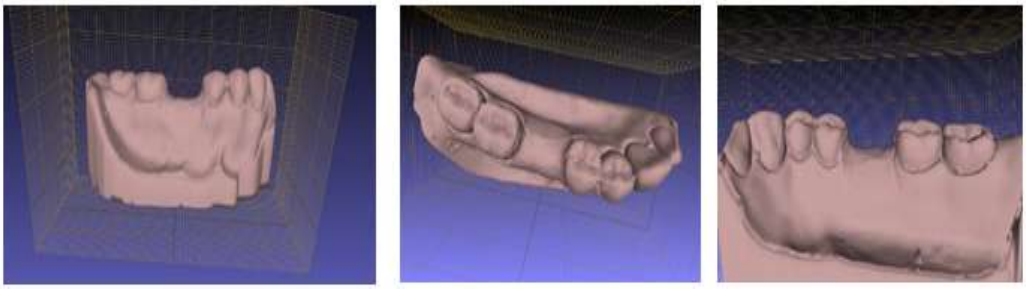

Figure 1. Imported models in the Meshlab software

IV. Results

The results obtained in our study of stereolithographic models, processed with appropriate software, make it possible to make a very accurate assessment of linear and volumetric bone changes preoperatively and postoperatively. With the help of the virtual model generated by the 3D Intraoral Scanner, we easily received information on the extent of bone resorption postoperatively with great precision - less than 10 μm.

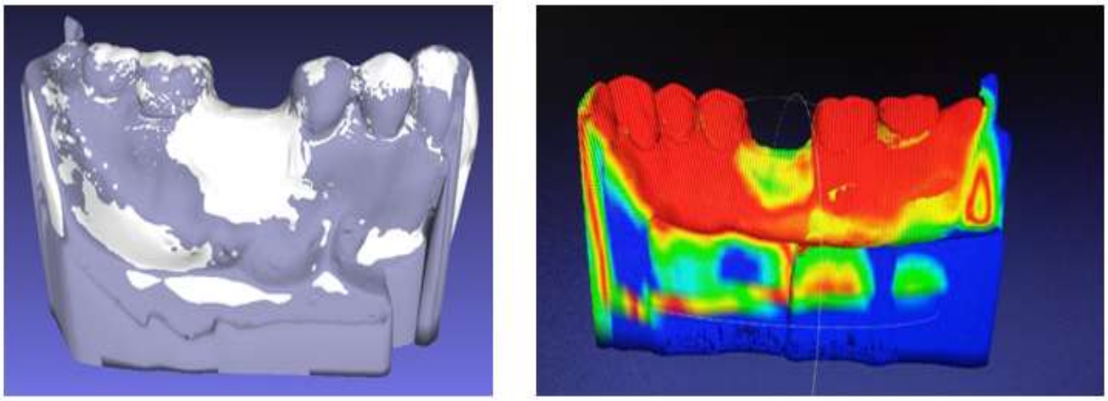

Figure 2. Vertex quality and color map denoting the differences in the two models

V. Discussion

The physiological changes in the alveolar ridge that occur after tooth extraction can result in up to 50% volumetric loss, which can compromise the aesthetic result of the future implant placement and prosthetic restorations.[7,8] The amount of vertical and horizontal resorption of the socket walls has been investigated with different methods, ranging from studying and measuring plastic cast models, to radiographic analysis, a clinical assessment with individually pre-fabricated acrylic stents during re-entry surgeries and use of titanium pins as reference points.[9] Although well established in practice these methods have a number of drawbacks: they are time-consuming for the patient and the clinician; the patient is subjected to additional x-ray exposure; most of them increase the treatment/research cost; they are prone to measurement error.In the available literature, we did not found the use of the 3D intraoral scanner to evaluate post-operative bone resorption after tooth extraction.

The virtual study model generated from the 3D intraoral scan can give the researcher faster and easier way to assess the resorption pattern. The Trios intraoral scanner has unparalleled accuracy – below 20 micrometers and precision – below 10 micrometers, which surpasses all quoted methods.[10]The importing process in Meshlab is straightforward and can be done using the import dialog or through the implemented "drag and drop function". Both models appear as different layers in the right panel of the program. Since they are equally oriented in the world coordinate system the models first appear superimposed but with some discrepancies. (Fig. 3)

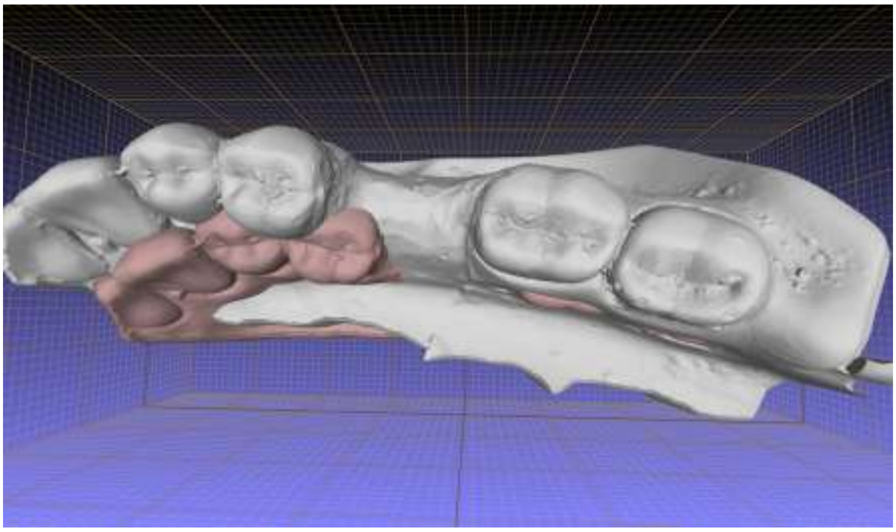

Figure 3. Initial superimposition of the STL models

Iterative Closest Point (ICP) algorithm automatically aligns both models based on the corresponding nearest points. This method was used to find the best rigid transformation that brought the points of a first mesh onto the corresponding points of a second one, within the same reference space. The "best fit" algorithm assumes the biggest fitting area for the correct positioning. With the functions: "Use as base mesh" and "Point mesh gluing", both models are oriented in such a way that the alignment procedure results in using the adjacent to the defect teeth's surface as a reference. In order to take real measurements from the models, an appropriate scale is set from the "Scale" dialog window.

Hausdorff distance is used to measure the discrepancies between the two models. The results appear in numeric format in the right panel of the program. A color-coded map can be produced in order to evaluate the areas and range of changes in the researched structures. With the use of "Boolean subtraction" the researcher can create a new 3D model resulting from the difference between the original two. The volume of the mesh is easily calculated and represents the volumetric change that is due to bone resorption.

Conclusion

The results obtained with this non-invasive method can provide accurate quantitative insights into the dimensional changes in the alveolar ridge after bone remodeling processes. The method can find a wide application in calculating bone resorption at a different time interval. Despite the small volume of the study, we believe that the proposed method can be very useful for a comparative assessment of postoperative bone resorption. It is necessary to check the possibilities of the proposed methodology in a clinical setting.

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