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AAO Foundation Final Report Form
(a/o 2/9/2021)

Please prepare a report that addresses the following:

Type of Award: Orthodontic Faculty Development Fellowship Award, 2019

Named the ***Robert M. Ricketts Sunflower Orthodontics Fellowship Award.***

Name(s) of Principal Investigator(s): Mohammed Elnagar

Institution: University of Illinois Chicago

Title of Project: Implementation of Dental Remote Monitoring Technology in Orthodontics: A prospective clinical study for access to care through the application of teledentistry.

Period of AAOF Support (e.g. 07-01-2019 to 06-30-2020) extension until 12-30-2021:

Amount of Funding: $20,000.

Summary/Abstract

Part 1: Accuracy of Remote Dental Monitoring Tooth Tracking Technology in Orthodontics

Dental Monitoring™ (DM™) is a multi-platform telehealth application system designed to aid orthodontists with tracking patient care at a distance. The software facilitates asynchronous interpersonal interactions through a HIPPA compliant system. It is touted for its ability to track tooth movement, identify emergencies and encourage oral hygiene improvement. The software relies on the patients to record photos of their dentition on a weekly basis and upload them to the Dental Monitoring™ app on their smartphone. From there the Dental Monitoring™ software engages deep learning AI technology through their patented tooth tracking algorithm and communicates the treatment progression to the orthodontist and the patient. Although this technology has been evaluated by others, to date there has yet to be an in-vivo study utilizing fixed orthodontic treatment corroborating the ability of this technology to track tooth movement.

Study Significance

The significance of this study is underscored by the recent challenges encountered during the Covid-19 pandemic. Teleorthodontic systems are being utilized due to the increased need without validation in the literature. We envision the results from this study will provide greater insight into the efficacy and scope of DM™'s AI facilitated remote tracking technology.

Specific Aim

The primary aim of this study is to examine the Dental Monitoring™ AI driven remote monitoring (AIRM) technology in an active clinical setting. Our objectives are to compare the accuracy and validity of STL files remotely generated from the Dental Monitoring™ application to STL files generated from the iTero® Element™5D intraoral scanner of patients' dentition during in-vivo fixed orthodontic treatment.

Null Hypotheses

H0A: There are no mean differences between 3D digital dental models remotely reconstructed by the Dental Monitoring™ application on patient smart phones and the 3D digital dental models generated by the iTero® Element™ 5D intraoral scanner during in-vivo fixed orthodontic treatment.

H0B: There are no significant differences in average deviation between the maxilla and mandible when the 3D digital dental models remotely reconstructed by the Dental Monitoring™ and the 3D digital dental models generated by the iTero® Element® 5D intraoral scanner are superimposed.

Methods

Patients undergoing fixed orthodontic treatment with traditional brackets or bands at the UIC COD Department of Orthodontics were recruited to participate in this study. Of the 26 patients enrolled, 24 completed the study. The participants ranged from 14-55 years of age. Treatment was tracked across an average of 13 months. A chart for each patient subject was created within the DM™ account and linked to the patient's smartphone app. Both arches of each patient were scanned with an iTero®Element™ to produce an initial 3D model prior to tooth movement. The STL file of each arch was uploaded to the patient's DM™ chart and used as a baseline reference for the software's calculations. A DM™ scan and iTero® scan was taken at treatment initiation both with (T1) and without (T0) the fixed orthodontic appliances and at every future in-person adjustment appointment (T2-T10). Patients also continued the Dental Monitoring™ scans remotely from home once a week throughout the study period. The 3D STL file produced from the remotely reconstructed models from the DM™ scans and the 3D STL file from the iTero® Element™ reconstructed models were then superimposed using the 3D-compare analysis in Geomagic Control-X 2020 (3D Systems, Rock Hill, SC) 3D inspection and metrology software to calculate the global deviation between the two models based on the best fit alignment of the dentition. Descriptive analysis was used to determine the mean deviation at each time point for the maxillary and mandibular arches. One-sample t tests were used to compare the maxilla and mandible mean deviations at each time point to the null hypothesis mean of 0 mm. The paired mean of the average at each time point in the sample was compared between the maxilla and mandible using the paired sample t-test.

Conclusion

The findings of this in-vivo investigation revealed there was no clinically significant difference between the reconstructed digital models generated by the iTero® Element™ 5D intraoral scanner and the remotely reconstructed digital dental models generated by the Dental Monitoring™ application. Clinical significance was set to +/-0.5mm based on the American

Board of Orthodontics (ABO)–determined standards.

Part 2: Clinical Assessment of Dental Monitoring Oral Hygiene Protocol: A Prospective Study

Objective: To assess the longitudinal relationship of oral hygiene in orthodontic patients taking weekly Dental Monitoring (DM) scans and to evaluate the validity and accuracy of DM artificial intelligence (AI) image analysis in identifying periodontal conditions.

Methods: Patients (n=24) from the UIC patient population seeking orthodontic therapy were evaluated clinically and with DM's AI image analysis software for the presence of plaque, gingivitis, and recession over the course of 18 months. The periodontal indices used for clinical evaluation were the Orthodontic Plaque Index (OPI) and the Modified Gingival Index (MGI). The periodontal trends over time were compared to a control group (n=25) also undergoing orthodontic therapy at UIC. Student independent t-test and paired t-tests were used to investigate the mean differences between study groups and between time points for each group respectively. Sensitivity, specificity, positivity predictive value (PPV), negative predictive value (NPV) were calculated to evaluate AI and clinical assessment of plaque, gingivitis and recession.

Results: The mean values for OPI and MGI after four months of treatment (T2) are lower in the DM group (OPI=1.96, MGI=1.56) than in control group (OPI=2.41, MGI=2.17), p-value < 0.05. There are statistically significant mean differences for OPI and MGI between time points (T2-T1) for each group, p-values < 0.001. There are mean differences for OPI and MGI between DM and control groups when comparing the time point differences (T2-T1), but these results are not statistically significant, p-values > 0.05. For AI detection of plaque, gingivitis, and recession, the sensitivity was 0.94, 0.96, and 0.99, the specificity was 0.53, 0.35, and 0.24, the PPV was 0.27, 0.29, and 0.70, and the NPV was 0.98, 0.96, 0.95 respectively.

Conclusions: Current results show that the oral hygiene of orthodontic patients rapidly worsens over the first three months and plateaus after about five months of treatment. Results also show that weekly DM scans may improve oral hygiene over time in orthodontic patients. DM AI image analysis software has high sensitivity and NPV and moderate specificity and PPV for detecting the presence of plaque, gingivitis, and recession in orthodontic patients.

Detailed results and inferences:
Two Complete manuscripts are ready to be submitted for publication.

Respond to the following questions:

1. Were the original, specific aims of the proposal realized? yes
2. Were the results published? **Two Complete manuscripts are ready to be submitted for publication.**

    a. If so, cite reference/s for publication/s including titles, dates, author or co-authors, journal, issue and page numbers **NA**
    b. Was AAOF support acknowledged? **Yes**
    c. If not, are there plans to publish? If not, why not? **NA**
3. Have the results of this proposal been presented?
    a. If so, list titles, author or co-authors of these presentation/s, year and locations
    Yes, the work presented at
        - **Clinic & Research Day 2022 - UIC College of Dentistry.**
        - **Graber Seminar 2021 UIC College of Dentistry.**
        - **AAO Annual meeting 2022**

    b. Was AAOF support acknowledged? **Yes**
    c. If not, are there plans to do so? If not, why not?
1. To what extent have you used, or how do you intend to use, AAOF funding to further your career?

AAOF's support had a significant impact on my career. The research projects would not have been conducted without the AAOF fund. The fund enabled me to compensate 50 patients for participating in the study and purchasing 3D analysis software to analyze the data. The results are very beneficial to the orthodontics community and helped me to apply for another research grant. The funds were also used to support my development as a clinician and an educator

Accounting for Project; (i.e.), any leftover funds, etc.
There were no leftover funds

Accomplishments during the award cycle:

Refereed Journal Articles:

1. Makki A, Elnagar MH*, Sanchez F, Caplin J, Viana G, Hasan Z, Obrez A, Kusnoto B. Assessment of Handicapping Labio-Lingual Deviation index scoring methods and their effect on orthodontic treatment coverage by Medicaid. J Public Health Dent. 2022 Feb 16. doi: 10.1111/jphd.12505. Epub ahead of print. PMID: 35174496.
2. Elnagar MH, Handelman CS,Lippincott JS, Kim M-R,BeGole E. Alveolar cortical plate changes associated with incisor retraction and its influence on the limits of orthodontic tooth movement. Orthod Craniofac Res. 2021;00:1–7.
3. Talaat S, Kaboudan A, Elnagar MH ,Talaat W, Kusnoto B, Sanchez F, , Ahmed Ghoneima A, Bourauel C. Artificial Intelligence For Detecting, Assessing Malocclusion And Treatment Needs. Semin Orthod 2021;27:164–171.
4. Talaat S, Kaboudan A, Talaat W, Kusnoto B, Sanchez F, Elnagar MH, Ghoneima A, Bourauel C. Improving the accuracy of publicly available search engines in recognizing and classifying dental visual assets using convolutional neural networks. Int J Comput Dent. 2020;23(3):211-218. PMID: 32789308.
5. Atsawasuwan P., Shirazi S., Altun S., Chmil C., Seagraves A., Viana G., Elnagar M. (August 5th, 2020). Extracellular MicroRNA Expression in Gingival Crevicular Fluid During Tooth Movement, Craniofacial Growth Series Volume 57th, Proceedings of the 45th Annual Moyers Symposium. University of Michigan at Ann Arbor. Available from: https://deepblue.lib.umich.edu/handle/2021.42/166464.
6. Elnagar MH, Aronovich S, Kusnoto B. Digital Workflow for Combined Orthodontics and Orthognathic Surgery. Oral Maxillofac Surg Clin North Am. 2020 Feb;32(1):1-14.
7. Jones JP, Elnagar MH, Perez DE. Temporary Skeletal Anchorage Techniques. Oral Maxillofac Surg Clin North Am. 2020 Feb;32(1):27-37.
8. Hoye L, Morris R, Elnagar MH*, Atsawasuwan P, Boquiren N, Caplin J , Viana G, Obrez A, Kusnoto B. Accuracy of Dental Monitoring 3D Digital Dental Models Using Photo and Video Modes. Am J Orthod Dentofacial Orthop. 2019 Sep;156(3):420-428.

Book Chapter:

1. Venugopalan S.R., Elnagar M.H., Karhade D.S., Allareddy V. (2021) Assessment of Outcomes by Using Machine Learning. In: Ko CC., Shen D., Wang L. (eds) Machine Learning in Dentistry. Springer, Cham. https://doi.org/10.1007/978-3-030-71881-7_11.
2. Allareddy V., Maclaine J., Elnagar M.H. (2022) Principles of Orthodontic Management of Treacher Collins Syndrome. In: Yates D.M., Markiewicz M.R. (eds) Craniofacial Microsomia and Treacher Collins Syndrome. Springer, Cham. https://doi.org/10.1007/978-3-030-84733-3_22.