

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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ALIGN TECHNOLOGY, INC.,  
Petitioner,

v.

DENTAL MONITORING SAS,  
Patent Owner.

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Case No. IPR2024-00110  
Patent No. 11,109,945

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**DECLARATION OF DR. HASSAN FOROOSH**

ALIGN EXHIBIT - 1002

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I, Hassan Foroosh, declare as follows:

**I. QUALIFICATIONS**

1. I have been retained by counsel on behalf of Align Technology, Inc. to provide opinions in this matter related to my experience and expertise. My opinions are based on my skills, knowledge, training, education, and experience in matters of this nature, and my examination of the materials utilized in preparing this report.

2. I am a Professor of Computer Science at the University of Central Florida. My primary research interests include image/video processing, computer vision, machine learning, and image-based modeling, including 3D modeling.

3. I received my Ph.D. in Computer Science from INRIA (French National Institute for Research on Informatics and Control), University of Nice Sophia Antipolis in 1996. I also earned a Master of Science in Computer Science from the University of Nice Sophia Antipolis in 1993, a Master of Science in Electrical Engineering from Kingston University, U.K., in 1990, and a Bachelor of Science in Electrical Engineering from Kingston University, U.K., in 1989.

4. Prior to research and teaching, I worked as an R&D Engineer at Innovative Engineering Solutions Ltd. in London from 1990 to 1992. Between 1993 and 1996, I served as a Research Assistant in the Scene Analysis and Symbolic Image Processing Group of INRIA, where I performed research in areas

such as 3D super-resolution, imaging processes for registration, and shape perception. From 1997 to 2000, I served as an Assistant Research Scientist at the University of Maryland, College Park, where I investigated topics such as image registration (2D and 3D), super-resolution of video data for unmanned aerial vehicles, super-resolution of Synthetic Aperture Radar (SAR) and Foliage Penetrating SAR (FOPEN-SAR), Automatic Target Detection and Tracking (ATD/R). During this time, I authored one of the most cited works on registration and alignment based on phase correlation: (Hassan Foroosh (Shekarforoush), Josiane Zerubia and Marc Berthod, Extension of Phase Correlation to Sub-pixel Registration, IEEE Transactions on Image Processing, vol. 11, Issue 3, pp. 188-200, 2002). Between 2000 to 2002, I served as Senior Research Scientist at the University of California, Berkeley where I also served as the Technical Coordinator and Principal Research Scientist of a Multi-University Research Initiative (MURI) funded by the Office of Naval Research. As part of the project, I conducted research on multi-sensor acquisition of 3D data for autonomous 3D modeling and visualization.

5. I joined the Department of Computer Science at the University of Central Florida (UCF) as an Assistant Professor in 2002. Since then I have served as an Associate Professor, Professor, and CAE Link Professor of Computer Science in the same department. I also served in various capacities in the

department, such as the Graduate Program Coordinator, chair of various leadership committees, and most recently in the Faculty Senate Strategic Planning Council for UCF. I have taught a number of courses directed to computer vision and 3D modeling, including: 3D Computer Vision, Image Processing, Special Topics in 3D Computer Vision, and Visual Simulation.

6. I have conducted extensive research in the field of 3D computer vision and computer modeling. Some example research projects that I have conducted include *Video Analysis Techniques for Terrain Modeling and Automated Texture Mapping* (2006-2007) and *Modeling and Visualization of Musculoskeletal Structures in Dental CT-Scan* (2006-2007). For the latter project, I developed algorithms for 3D registration, modeling and visualization of maxilla and mandible of patients for dental surgery using Computer Aided Tomography (CAT) scanning.

7. I have been the principal investigator or co-principal investigator of numerous research projects funded by the National Science Foundation (NSF), NASA, DoD, and industry, with total funding exceeding \$14M since joining UCF. As one example, I recently served as the principal investigator in two projects funded by the National Science Foundation (NSF) on 3D modeling and the role of 3D information in machine understanding of digitized world. One project was directed to the registration/alignment of dental CT scans of patients over a period

of time during the treatment of a patient, with the purpose of improving the quality of 3D models, e.g., corrections and noise removal in 3D CT scans.

8. I have authored or co-authored over 180 articles in peer reviewed journals or conference proceedings. Some example publications include M. Berthod, H. Shekarforoush (Foroosh), M. Werman and J. Zerubia, *Reconstruction of High Resolution 3D Visual Information*, Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pages. 654-657 (1994); C. Früh, J. Flynn, H. Foroosh, and A. Zakhor, *Fast 3D model generation for urban environments*, Workshop on the Convergence of Graphics, Vision, and Video (CGVV'01), Berkeley, March 2001; Jiangjian Xiao, Xiaochun Cao, and Hassan Foroosh, *3D Object Transfer Between Non-Overlapping Videos*, Proceedings of IEEE Virtual Reality Conference, pages 127-134, (March 25-29, 2006); M. Balci, M. Alnasser, and H. Foroosh, *Subpixel Alignment of MRI Data Under Cartesian and Log-Polar Sampling*, Proceedings of IAPR International Conference on Pattern Recognition (ICPR), vol.3, pages 607-610 (2006); M. Balci, M. Alnasser, and H. Foroosh, *Alignment of Maxillofacial CT Scans to Stone-Cast Models Using 3D Symmetry for Backscattering Artifact Reduction*, Proceedings of Medical Image Understanding and Analysis Conference (MIUA) (2006); and A. Tariq and H. Foroosh, *Designing a Symmetric Classifier for Image Annotation using Multi-Layer Sparse Coding*, *Image and Vision Computing (IVC)*, Image and Vision Computing (IVC) (2018)

(initially published as *Image Annotation using Multi-Layer Sparse Coding*, at <https://arxiv.org/pdf/1705.02460> (May 6, 2017)).

9. Since joining UCF, I have advised and chaired the dissertation of over 30 doctoral students, 25 of whom have already successfully defended their doctoral dissertation, and secured academic positions or industry jobs in major high-tech corporations. As one example, I served as the advisor for a dissertation directed to “*Sub-pixel Registration in Computational Imaging and Applications to Enhancement of Maxillofacial CT Data*”. This research project focused on registration and alignment of 2D images and 3D digitized data obtained by dental CT scans and dental imprints of a patient (e.g., casts), with the aim of improving the quality of CT scans, e.g., eliminating backscattering issues. Methods were developed to register CT models to the physical imprints of patients (e.g., a stone cast model of the patient’s teeth).

10. I have been serving as the editor and/or committee member on numerous professional organizations. For instance, I have been involved with the following organizations: IEEE Transactions on Image Processing (Associate Editor, 2003-2008, 2011-2016); IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (Member, Technical Committee, 2004-2012, 2015-2016, 2019-2020); IEEE Transactions on Pattern Analysis and Machine Intelligence (Reviewer, 1996-present).

11. For my work, I have been honored with numerous awards, including the *Piero Zamperoni Award*, International Association for Pattern Recognition (IAPR) (2004). I have also received several Best Paper awards, including “*The Best Scientific Paper Award*” in the IAPR International Conference on Pattern Recognition in 2008, “*The Best Paper Award*” in the IEEE International Conference on Image Processing (ICIP) in 2018, and the *Distinguished Researcher*, UCF College of Engineering and Computer Science (2004-2005, 2005-2006).

12. In sum, I have studied, taught, practiced, and conducted research in the area of computer vision and computer modeling of physical structures, including dental structures.

13. A copy of my *Curriculum Vitae*, attached as EX1003, contains further details on my education, experience, publications, and other qualifications to render an expert opinion in this matter.

## **II. SCOPE OF WORK**

14. I understand that a petition is being filed with the United States Patent and Trademark Office for *Inter Partes* Review of U.S. Patent No. 11,109,945 to Salah et al. (“the ’945 patent,” EX1001), entitled “Method of Evaluating an Orthodontic Aligner.”

15. I have been retained by Align Technology, Inc. (“Align”) to offer an expert opinion on the validity of claims 1-2 and 4-6 of the ’945 patent assigned to Dental Monitoring SAS (“Dental Monitoring”). I receive \$650 per hour for my services. No part of my compensation is dependent on my opinions or on the outcome of this proceeding.

16. I have been specifically asked to provide my opinion on the unpatentability of claims 1-2 and 4-6 of the ’945 patent. In connection with this analysis, I have reviewed the ’945 patent. I have also reviewed and considered various other documents in arriving at my opinions and may cite to them in this declaration.

### **III. LEGAL STANDARDS**

17. I understand that a claim is not patentable under 35 U.S.C. §102 as anticipated if the claim as a whole is described, either expressly or inherently, in a single prior art reference. I understand that this also requires that the prior art reference disclose that each claim element is arranged as recited in the claims.

18. I understand that differences between the prior art reference and a claimed invention, however slight, invoke the question of obviousness, not anticipation.

19. I have been advised that a claimed invention is not patentable under 35 U.S.C. §103 if it is obvious. A patent claim is unpatentable if the claimed

invention would have been obvious to a person of ordinary skill in the field at the time the claimed invention was made. This means that even if all of the requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill in the relevant field who knew about all this prior art would have come up with the claimed invention.

20. I have further been advised that the ultimate conclusion of whether a claim is obvious should be based upon several factual determinations. That is, a determination of obviousness requires inquiries into: (1) the level of ordinary skill in the field; (2) the scope and content of the prior art; (3) what difference, if any, existed between the claimed invention and the prior art; and (4) any secondary evidence bearing on obviousness.

21. I have been advised that, in determining the level of ordinary skill in the field that someone would have had at the time the claimed invention was made, I should consider: (1) the levels of education and experience of persons working in the field; (2) the types of problems encountered in the field; and (3) the sophistication of the technology.

22. I have also been advised that, in determining the scope and content of the prior art, in order to be considered as prior art, a reference must be reasonably related to the claimed invention of the patent. A reference is reasonably related if

it is in the same field as the claimed invention or is from another field to which a person of ordinary skill in the field would look to solve a known problem.

23. I have been advised that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. In evaluating whether such a claim would have been obvious, I may consider whether there is a reason that would have prompted a person of ordinary skill in the field to combine the elements or concepts from the prior art in the same way as in the claimed invention.

24. I have been advised that any obviousness rationale for modifying or combining prior art must include a showing that a person of ordinary skill would have had a reasonable expectation of success.

25. I have been further advised that there is no single way to define the line between true inventiveness on the one hand (which is patentable) and the application of common sense and ordinary skill to solve a problem on the other hand (which is not patentable). For example, market forces or other design incentives may be what produced a change, rather than true inventiveness. I may consider whether the change was merely the predictable result of using prior art elements according to their known functions, or whether it was the result of true inventiveness. I may also consider whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the

patent. I may consider whether the innovation applies a known technique that had been used to improve a similar device or method in a similar way. I may also consider whether the claimed invention would have been obvious to try, meaning that the claimed innovation was one of a relatively small number of possible approaches to the problem with a reasonable expectation of success by those skilled in the art.

26. I understand that hindsight must not be used when opining on the patentability of claims of a patent. Therefore, my opinion will reflect the understanding of a person of skill in the art as of the relevant patent application filing dates, which I have been instructed is June 9, 2017, for this matter, the earliest date to which applicants have claimed priority for the claims of the '945 patent.

#### **IV. BACKGROUND IN THE ART**

27. The '945 patent describes methods involving computer vision and deep learning, with specific focus on analysis of dental images, such as images of the teeth of patients wearing an aligner. In the background below, I provide a brief overview of some important elements of computer vision and deep learning that are relevant to understanding what a POSA would have known in these areas at the time of filing of the '945 patent.

## **A. Image Analysis and Computer Vision**

28. Images are a rich source of information that humans typically manage to analyze with relative ease. Image analysis is often described as the process of extracting information from images that may be subsequently used by either humans or computers to perform certain tasks. Developing methods and computer algorithms to provide the capability of extracting accurate and meaningful information from images has been the subject of study in computer vision in the past few decades.

29. Historically humans have been outperforming computers in tasks that require recognition and understanding of images in terms of their contents and the contextual relationships. It was not until after the early years of the last decade, with major breakthroughs in machine learning techniques (both in terms of architecture and hardware support, and including the advancement of deep learning) that computers managed to also outperform humans in tasks such as recognition and image content and context understanding. *See* EX1015, 1-2, 8. Developments of parallel processing hardware (in particular Graphic Processing Units) made it possible for deep learning networks to be trained in an end-to-end manner and on much larger training sets, typically many orders of magnitude larger than before, involving tens of thousands to millions of images.

30. Computer vision is often described in layman's terms as the science of making computers see. One way to conceptually divide vision tasks, based on ideas pioneered by David Marr, divides such tasks into three levels: low-level, mid-level, and high-level tasks (also referred to as computation, algorithm, and implementation tasks). EX1016, 1538-39, 1541. Accordingly, computer vision algorithms were traditionally developed to handle low-level, mid-level, and high-level vision problems. Low-level computer vision refers to computational methods and algorithms that process images at pixel-level, modifying pixel properties to achieve tasks such as quantization, encoding, image restoration, image enhancement, etc. Mid-level computer vision refers to computational methods to produce feature-level representations of images, such as color features, edge features, 3D geometric features, etc. A common feature-level representation widely used in computer vision tasks is boundary-based representations, such as edges and contours that define the separation between regions in images. Finally, high-level computer vision refers to computational methods and algorithms that aim to understand image contents and contextual relationships, including tasks like object classification, object localization, object instance recognition, etc.

31. Low-level and mid-level processing steps can be intermediate steps towards performing high-level vision tasks. For example, one may perform some restoration or enhancement (low-level) before extracting edges (mid-level) to align

the edges with a template contour (low-level) to determine the presence and location of an object in the image (high-level), or to recognize an object or its class (high-level).

32. There were several motivating factors that led to the development of machine learning techniques, including deep learning methods, in computer vision. One of these motivating factors was to overcome certain shortcomings, such as the treatment of different visual levels independently, as opposed to the way that humans integrate all levels of vision into a unified process. This led to a new class of computer vision methods that are designed to learn features from data, but also made it possible to take advantage of high-level labels to learn better features, while still relying also on low-level image properties and values to extract features. This also made it possible for these methods to allow a network to learn all it needs in order to solve for a vision task, taking raw image data directly as input.

### **B. Edge Detection and Contour Detection**

33. Edges, contours, boundaries, and discontinuities are various terms that have been used interchangeably in the literature to refer to similar concepts involving a representation of a discontinuity in an image. Edges and contours have long been considered as important features used for performing various high-level computer vision tasks, such as classification, object recognition, instance identification, etc. They have also been proven extremely useful for other low-level

vision tasks, such as registration and alignment, or template matching that lead to high-level processing and annotation.

34. Classical edge detection was based on low-level properties, such as detected discontinuities, which would then be assigned a binary label (e.g., a 0 or 1) to identify the location of edges. Due to the key role of edges in computer vision and the rising influence of machine learning methods, researchers developed machine-learning based methods (including what would come to be referred to as deep learning) for edge and contour detection. EX1017, 1-2; EX1007, Abstract. Whereas traditional edge and contour detectors used binary labels (1 and 0) for edge locations, the development of machine learning tools permitted image processing software to assign multiple labels in the feature space (i.e. the contour image). EX1017, 5-9; EX1007, 8, 9-12; *see also* EX1008, 18:14-17 (1 or 0 used to denote edges). What this means is that each contour is labeled differently based on various different high-level labels (e.g., class, instance, etc.) reflecting what is depicted within the region for which the contour is a boundary. For instance, contours of an object class A might be labeled as 1, those of an object class B as 2, those of an object class C as 3, and so on and so forth. These labels can be located on the contours of the object or assigned to the pixels in regions defined by the contour. EX1007, 9-12. Thus, deep-learning methods allow categorization of different objects in an image into specific classes.

35. These type of contours or boundaries are sometimes referred to as “category-specific” or “semantic” contours of boundaries. EX1017, 9; EX1007, 11. Thus, if a neural network is trained to look for features based on a training set with high-level labels (e.g., class labels), the trained machine would be able to return also features (e.g., edges) that are specific to that class. For instance, if a machine is trained to look for the contours of different types of teeth in intraoral images, it would not only detect edges (as in classical methods) but also would be able to label edges and the regions they define based on which type of tooth they belong to instead of a simple binary labeling.

## **V. THE '945 PATENT**

36. The '945 patent is entitled “Method of Evaluating an Orthodontic Aligner.” EX1001, cover. The '945 patent describes acquiring one or more dental images, including images of a patient’s teeth and of an aligner worn on the teeth (which optionally may be just a single image depicting both), and analyzing the image or images to evaluate the shape of an aligner worn by a patient. EX1001, Abstract, 2:4-9, 2:57-58 (“alternatively, said dentition and aligner images are one and the same image”). The '945 patent uses the term “updated image” to refer to any such image taken of the teeth. EX1001, 5:47-49. Independent claim 1 recites as follows:

1. A method for evaluating the shape of an orthodontic aligner worn by a patient, said method comprising the following steps:

1) acquisition of at least one two-dimensional image of teeth of said patient, referred to as “updated image”, under actual acquisition conditions;

at least one updated image referred to as “aligner image”, at least partially representing the aligner in a service position in which it is worn by said teeth; and at least one updated image referred to as “dentition image”, identical to or different from the aligner image, representing said teeth,

2) if the dentition image is different from the aligner image, conversion of the dentition image so that it represents said teeth as seen under the acquisition conditions used during the acquisition of the aligner image in step 1);

3) determination, by means of image processing software, for each of a plurality of teeth represented on the dentition and aligner images, of interior and exterior tooth outlines representing the outline of the free end of said tooth on the dentition and aligner images, respectively;

4) comparison of the interior and exterior tooth outlines, so as to determine at least one score according to said comparison.

EX1001, 13:59-14:17. Summarized, claim 1 includes steps of acquiring one or more images of a patient’s teeth, at least one of which (the “aligner image”) shows the aligner worn on the patient’s teeth and at least one of which (the “dentition image”) shows the patient’s teeth. These images may be the same image (i.e., an image showing both a patient’s teeth and the aligner worn on the teeth). If the two

images are different, the dentition image is converted to represent teeth as seen under acquisition conditions used to acquire the aligner image. For each of the aligner and dentition images, outlines are determined—the “interior tooth outline” corresponding to the outline of the ends of teeth and the “exterior tooth outline” corresponding to the surfaces of the aligner. These outlines are then compared to determine a score.

37. Of particular relevance to the analysis I provide below is the alternative, encompassed by claim 1, in which the dentition and aligner images are the same image. In this alternative, claim 1 requires only the following steps: (a) acquiring an image (being both the dentition and aligner images) depicting both the patient’s teeth and an aligner worn on the teeth; (b) determining outlines of both the teeth and the aligner; and (c) comparing those outlines to determine at least one score. In this alternative, step (2) of claim 2 is not required.

38. Dependent claim 2 recites comparing the score against an acceptability threshold and emitting information according to the result of the comparison. EX1001, 14:18-22. Dependent claim 4 recites that the aligner and dentition images are the same image—corresponding to the alternative I discussed in the previous paragraph. EX1001, 14:38-39.

39. Dependent claim 5 provides details indicating that the score recited in step (4) of claim 1 involves determining distances between the interior and exterior

tooth outlines (i.e., distances from teeth to aligner) and comparing the distances to a threshold. EX1001, 14:40-53. In particular, a distance between the interior and exterior outlines is determined for each tooth, and a threshold is determined, with a difference score determined based on comparison of each tooth's distance to the threshold. *Id.* The threshold may be determined based on the measured distances; however, the claim indicates that this is only preferred, not required by the claim, indicating that the claim also encompasses embodiments in which the threshold need *not* be determined based on the measured distances. *Id.*; *see also id.*, 11:51-12:5 (discussing some options for determining scores based on thresholds that optionally depend on measured distance). For example, a fixed threshold might be used which could be determined on some other basis than the measured distances.

40. Dependent claim 6 indicates that the distances recited in claim 5 are measured in pixels. EX1001, 14:54-55. As I explain in further detail below in section IX, each of the dependent claims merely add routine aspects known conventionally in the art and taught or suggested by the grounds references.

## **VI. PRIOR ART**

### **A. Kim**

41. U.S. Patent Publication No. 2017/0281313 (“Kim,” EX1005) is entitled “Method and System for Providing Remote Teeth Alignment Services and Computer-readable Medium on which the Method is Recorded.” Kim was filed on

April 5, 2016, and published on October 5, 2017. I understand that Kim may be considered in evaluating the patentability of the claims of the '945 patent.

42. Kim teaches methods and systems to provide “remote teeth alignment services.” EX1005, Abstract. Kim teaches methods by which an orthodontist can be provided “accurate teeth alignment information using a device, e.g., a smartphone, of an orthodontic patient,” including information allowing the orthodontist to “diagnose the condition of the patient based on the teeth alignment information” transmitted as well as to “remotely provide information about an accurate step of a clear aligner to be currently worn by the orthodontic patient.” EX1005, ¶10. Kim refers to the patient’s smartphone as an “orthodontic patient terminal,” though Kim notes that a variety of other patient devices, such as mobile devices, laptop computers, smart cameras or camcorders, and similar devices may also be used. EX1005, ¶¶41-42.

43. Kim teaches obtaining teeth alignment information by taking a variety of photographs of the patient’s teeth from different angles. EX1005, ¶¶55-56. Additionally, Kim teaches that the patient’s smartphone can send “clear aligner information about a currently worn clear aligner” to the orthodontist. EX1005, ¶66. This information is transmitted “in such a manner that the orthodontist checks a photo or a video of the clear aligner currently worn by the orthodontic patient, and

determines whether the clear aligner is normal and corresponds to an appropriate step.” *Id.*

## **B. Invisalign**

44. The Invisalign Clinical Monitoring Guide (“Invisalign,” EX1006) was published in 2003. EX1006, i. Invisalign was archived by the Internet Archive at [http://web.archive.org/web/20030926024959/http://www.invisaligncec.com:80/consistent/pdfs/ICMG\\_Final.pdf](http://web.archive.org/web/20030926024959/http://www.invisaligncec.com:80/consistent/pdfs/ICMG_Final.pdf), reflecting an archive date of September 26, 2003, indicating it was published no later than that date. I understand that Invisalign may be considered in evaluating the patentability of the ’945 patent.

45. Invisalign teaches methods for monitoring progress of orthodontic treatment when using clear plastic aligners manufactured by Align Technology, Inc. EX1006, i. The guide describes how orthodontic patients’ treatment progress can be monitored after the patient has received aligners and the aligners are being worn by the patient. *Id.* Invisalign identifies key considerations for effective use of aligners in treating patients, and it also describes the need to use high-quality records, including both dental impressions and photographs of the teeth of the patient wearing the aligners. EX1006, ii-iv.

46. Invisalign also provides specific examples of measurements to perform to track whether aligners are properly treating patients, as well as discussing what those measurements indicate about whether the aligner is

appropriate in terms of fit, seating, and other properties. *See, e.g.*, EX1006, 1-2. In one example, Invisalign illustrates how poor aligner seating may be assessed, showing with a digital photograph of an aligner on a patient's teeth how a poor fit can be determined. *See* EX1006, 1. In the example photograph, the poor fit is shown by the presence of a gap of over 1 mm between the ends of the teeth and the corresponding parts of the aligner that receive each tooth. *Id.* This photograph is shown below; the image in Invisalign includes overlaid arrows pointing out the gaps that are visible for multiple teeth. *Id.*



**C. Salah**

47. PCT Publication No. WO2016066651 to Salah et al. (“Salah,” EX1008) is entitled “Method for Monitoring Dentition.” Salah was published in

French, but I understand that EX1008 is a certified translation of Salah. Salah names 4 inventors in common with the '945 patent. Salah was published on May 6, 2016, more than 1 year before the earliest claimed priority date of the '945 patent. Accordingly, I understand that Salah may be considered in evaluating the patentability of the claims of the '945 patent.

48. Salah discloses methods for monitoring patients' teeth, which can be helpful to track the teeth during orthodontic treatment. EX1008, Abstract, 1:12-22, 8:10-18. Two-dimensional images can be obtained of a patient's teeth, and these images can be compared to a three-dimensional model of the patient's teeth, allowing the model to be updated and used to measure progress of treatment. EX1008, 1:26-2:19, 46:15-19, Fig. 1. Salah's analysis of images can include using contour detection on an acquired image to determine edges of intraoral structures such as teeth and aid mapping to a reference model. EX1008, 34:11-14, 36:14. This contour detection can be performed with image processing software using any of a wide variety of methods. *Id.* Salah's list of methods appears to include a typographical error; the last item in the list uses the term "Deepleraning," but a POSA would have understood that Salah meant to be referring to "deep learning," as deep learning is a well-known method of computer analysis that has many uses, including specifically the detection of contours in images. EX1008, 36:14.

49. Salah teaches that its 2D images may be obtained by a patient or a relative using a device such as a cell phone, which can also perform the remaining steps of the evaluation process (including comparison to a 3D model). EX1008, 2:21-27, 31:4-7. Because the users may not have training in image acquisition or dentistry, Salah also teaches that the image-acquisition apparatus can guide the user to obtain appropriate images. EX1008, 27:21-28:10. For example, the apparatus can indicate whether the image is acceptable or needs to be retaken, and it can also provide indications (such as arrows or other instructions) indicating how to adjust the camera's positioning to correctly orient it to obtain an image. *Id.*

## **VII. OVERVIEW OF THE LEVEL OF SKILL**

50. I have been advised that “a person of ordinary skill in the relevant field” (or “person of ordinary skill in the art,” or “POSA”) is a hypothetical person to whom one could assign a routine task with reasonable confidence that the task would be successfully carried out. I have been advised further that, in determining the level of ordinary skill in the art that someone would have had at the time the claimed invention was made, I should consider: (1) the levels of education and experience of persons working in the field; (2) the types of problems encountered in the field; and (3) the sophistication of the technology.

51. In my opinion, a person of ordinary skill in the relevant field as of June 9, 2017, would typically have an advanced degree, such as a Masters' Degree

or Ph.D. in computer science or a related field, with at least two years of work in computer vision, image analysis, medical imaging, or related areas. A POSA could have less education but significant professional experience in one or more of these fields. A POSA could be a member of an interdisciplinary team including persons with backgrounds such as electrical engineering, computer science, optical imaging, and dentistry or orthodontics, and could call upon the knowledge of other team members as appropriate.

### **VIII. CLAIM CONSTRUCTION**

52. I have been advised that the claim terms of the '945 patent claim are to be given the plain and ordinary meaning that the terms would have to a person of ordinary skill in the art in question at the relevant priority date. I understand that the analysis focuses on how the patentee used the claim term in the claims, specification, and prosecution history. I also understand that dictionaries or other extrinsic sources may assist in determining the plain and ordinary meaning but cannot override a meaning that is unambiguous from the intrinsic evidence. I have followed these principles in my analysis throughout this declaration.

53. The scope of the challenged claims is discussed throughout my analysis; I provide additional discussion of some claim terms below.

### **A. aligner and dentition images**

54. Claim 1 of the '945 patent recites a “at least one updated image referred to as an ‘aligner image,’ at least partially representing the aligner in a service position in which it is worn by said teeth; and at least one updated image referred to as ‘dentition image,’ identical to or different from the aligner image, representing said teeth.” Claim 1 thus indicates that the aligner and dentition images may be different images, or may be the same. The second element of claim 1 begins “if the dentition image is different from the aligner image,” and claim 4 recites that “the dentition and aligner images are the same image.” These elements confirm that claim 1 that the dentition and aligner images may be the same image, which would be an image depicting both an aligner worn on the patient’s teeth and the patient’s teeth themselves. With regard to the second element of claim 1, because this element begins with “if the dentition image is different from the aligner image,” this indicates that when considering embodiments where the two images are the same image (as I discuss in detail below, and which corresponds to claim 4), the second element of claim 1 need not be performed. Indeed, the remainder of the second element of claim 1 addresses converting the dentition image to match the aligner image, which would not make sense where there was just a single image simultaneously embodying both the dentition image and the aligner image.

## **B. interior and exterior tooth outlines**

55. Claim 1 of the '945 patent recites determining “interior and exterior tooth outlines representing the outline of the free end of said tooth on the dentition and aligner images, respectively.” The specification of the '945 patent indicates that “a line may delimit the free end of [a] tooth,” in which case it is an “interior tooth outline.” EX1001, 5:10-13. The specification also indicates that “a line may also delimit part of the aligner,” in which case it is an “exterior tooth outline.” EX1001, 5:14-20. This description indicates that an “interior tooth outline” refers to a line delimiting a free end of a tooth and an “exterior tooth outline” refers to a line delimiting a part of an aligner.

## **IX. CLAIMS 1-2 AND 4-6 WERE OBVIOUS AS ILLUSTRATED BY KIM, INVISALIGN, AND SALAH**

### **A. The Combination of Kim, Invisalign, and Salah**

56. Kim discloses methods for providing remote tooth alignment services, including evaluation of a clear aligner to be worn by a patient and determination of, for example, “when a new or modified clear aligner is necessary.” EX1005, Abstract, ¶10. Kim describes providing these services using an “orthodontic patient terminal,” which may be a patient’s smartphone. EX1005, Abstract, ¶¶1, 10. 42. To facilitate these services, photographic or video images may be transmitted to an orthodontist to provide information about teeth alignment and the patient’s clear aligner. EX1005, ¶12. Kim also teaches that automatic recognition of contours of a

patient's face and teeth may be employed as part of the imaging process. EX1005, ¶14. As one example, Kim teaches providing a "teeth contour automatic-recognition photographing program for displaying a virtual teeth line on the screen of the orthodontic patient terminal and automatically recognizing and taking a photo of teeth of the orthodontic patient shown on the screen." *Id.*

57. Kim further describes how a "clear aligner information transmission program" may operate to provide orthodontists with images of aligners worn by the patient that may be usefully analyzed by the orthodontist. EX1005, ¶66. The program receives "clear aligner information about a currently worn clear aligner from the orthodontic patient terminal." *Id.* This clear aligner information can include a photo or a video which is stored and sent to the orthodontist. *Id.* Then, "the orthodontist checks a photo or a video of the clear aligner currently worn by the orthodontic patient, and determines whether the clear aligner is normal and corresponds to an appropriate step." EX1005, ¶66. Kim teaches that its techniques provide reduced diagnosis time and cost relative to traditional in-office visits, as well as providing for enhanced accuracy. *See* EX1005, ¶¶8-10, 72. For example, Kim allows remote monitoring to substitute for traditional visits to orthodontists' offices (*see* EX1005, ¶¶8-9), by allowing an orthodontist to "obtain accurate teeth alignment information using a device, e.g., a smartphone, of an orthodontic

patient,” allowing remote diagnosis, as well as increasing accuracy of diagnosis using images acquired of patients’ mouths. EX1005, ¶10.

58. Invisalign corroborates Kim’s teachings regarding imaging an aligner in a service position on teeth, showing how such an aligner may be assessed to determine if it fits appropriately. Moreover, Invisalign’s teachings make it readily apparent to do so in a system such as Kim’s. Invisalign specifically details assessments that can be used to determine whether the clear aligner is normal and corresponds to an appropriate step, teaching how to “successfully monitor Invisalign treatments and address issues that may arise between receipt of Aligners from Align to the completion of treatment.” EX1006, i. The first criterion identified by Invisalign addresses “General fit issues,” with Invisalign specifying that if an aligner is well seated, there will be a distance of less than 1 mm between the end of the teeth and the surface of the aligner. EX1006, 1. This type of separation is depicted in a digital photograph, where a poorly-seated aligner is shown being worn by a patient in a service position, with two arrows indicating that the aligner surfaces corresponding to teeth (i.e., the parts of the aligner’s tooth-shaped surfaces that match with the end of each given tooth) have a distance of greater than 1 mm from the ends of the teeth. *See id.* The resulting gap is plainly visible on the photograph. Describing the gap in terms appropriate for a computer-vision application, the gap corresponds to the space between the contour defining

the occlusal end of the teeth and the matching contour defining the occlusal surface of the clear aligner. The photograph is reproduced below, and the shapes of each surface can be naturally perceived by the human eye, with the edge of the teeth visible as a transition from white to black and the edge of the aligner being what the arrows point towards:



EX1006, 1. Thus, Invisalign teaches that orthodontic assessment of an aligner may include assessing the distance between the edges of the aligner and the patient's teeth when the aligner is worn, as may be seen in a digital photograph showing the patient's teeth as well as the clear aligner being worn in a service position on the patient's teeth.

59. In view of Kim's disclosure of orthodontic checking of a photo or video of an aligner currently worn by the patient and Invisalign's teachings of how to evaluate aligner fit, illustrated by an image of an aligner worn on a patient's teeth, a POSA would have had reason to analyze images of the teeth of a patient wearing an aligner in a service position to evaluate whether the aligner fits appropriately. This combination would be applying known methods for orthodontic evaluation of aligner fit based upon the appearance of the aligner worn on the patient's teeth, as taught by Invisalign, in order to analyze a photo or video of the aligner worn by the patient, as taught by Kim. This combination would predictably provide feedback regarding tooth-aligner separation to aid an orthodontist regarding whether the clear aligner is normal and corresponds to an appropriate step of treatment. As Kim indicates, employing such techniques would serve multiple goals. As one example, Kim teaches that accuracy would be enhanced. *See* EX1005, ¶¶10, 72. Kim also teaches that the time and cost of treatment may be reduced. *Id.* Further, implementing assessment as taught by Invisalign and Kim would facilitate remote assessment, reducing the burden of office visits for orthodontics patients. *See* EX1005, ¶¶8-10. Additionally, a POSA would have understood that the type of image analysis suggested by Kim and Invisalign could be readily applied on images or videos showing a clear orthodontic aligner being worn on the teeth of a patient. For example, a POSA

would have recognized that by using computer-vision techniques to detect the locations of the ends of the patient's teeth and the corresponding surfaces of the aligner, the distance between the two could be measured, corresponding to the assessment taught by Invisalign.

60. Not only are these types of images of aligners on teeth expressly depicted in Invisalign (*see* EX1006, 1), but the fact that POSAs were motivated to use such images for orthodontic evaluation was confirmed in publications by practicing orthodontists. For example, Dr. Scott Frey published a step-by-step guide on the Ortho Cosmos website explaining how to conduct a simple remote orthodontic monitoring system allowing orthodontists to analyze orthodontic patients' teeth and aligners over the internet. EX1009, 17-27. The guide explains that patients would be shown example photos or videos to show exactly what images they should capture, including one video "with teeth apart and aligners in." EX1009, 19. Patients could then record and transmit such videos with their smartphone, providing orthodontists with video images sufficient to conduct typical orthodontic treatment evaluations. EX1009, 20-27. Thus, published descriptions show that photographs or videos of the teeth of patients wearing aligners, including images taken with cellphones, were already known to be useful to analyze for orthodontic assessment purposes.

61. A POSA would have known how to determine the width of such gaps using image processing software. As I discussed briefly above, the distance between depicted teeth and a depicted aligner corresponds to the distance from the edge of one to the edge of the other. Salah provides disclosure useful for determining such edges. Like Kim, Salah teaches application of computer image analysis to dental images for orthodontic treatment purposes. Salah teaches methods that are useful for monitoring patient's teeth, for example, to track the teeth during orthodontic treatment, including steps of acquiring images of the patient's teeth at various times during treatment. EX1008, Abstract, 8:19-28. Salah teaches that the acquired images can include two-dimensional images, which may be acquired by an image acquisition apparatus such as a mobile phone. EX1008, 13:24-28, 31:4-9.

62. Further paralleling Kim, Salah teaches that images may be analyzed to “measure the effectiveness of orthodontic treatment,” including by “remotely monitor[ing] the progress of an orthodontic treatment.” EX1008, 46:15-24. Salah teaches that analysis of acquired images may include determining contours of objects in an image, including by using image processing software for contour or edge detection. EX1008, 34:5-36:14.

63. A POSA would have had reason to use image processing software, as taught by Salah, for contour detection to detect the edges of teeth and aligners.

Invisalign teaches that the gap between the surfaces of teeth and an aligner should be below a threshold value (1 mm) when fitting well, aligning with Kim's teaching to assess whether an aligner was "normal and corresponds to an appropriate step." EX1005, ¶66; EX1006, 1. As I explained above, the width of a gap between two depicted objects in an image (such as a tooth end and a surface of an aligner) corresponds to the distance between the contours for each object. Equivalently, the "gap" is a portion of the image between those surfaces, and its width is the distance from one side to the other (i.e., the distance from a contour separating "tooth" from "gap" and a contour separating "gap" from "aligner.>"). Thus, to apply Invisalign's teaching in the context of Kim and Salah, a POSA would have analyzed an image of an aligner worn in a service position on teeth by measuring the distances from the contour defining the ends of the teeth to the contour defining the surfaces of the clear plastic aligner, as detected by image processing software.

64. A POSA would have reasonably expected such a combination to work predictably and successfully. In combination, the elements taught by each reference would perform substantially the same function as they provide alone, applying image processing software to perform contour detection as taught by Salah to detect edges of teeth and aligners, producing a measurement of distance between these surfaces, as taught by Invisalign, to assess whether the imaged aligner fits appropriately for the current step in patient treatment, as taught by Kim.

This combination would be an application of well-known image processing techniques in a predictable manner to perform routine measurements of objects depicted in images, where those measurements have a known use for orthodontic assessment. A POSA would thus have a reasonable expectation of success of combining Kim, Invisalign, and Salah in this manner to arrive at the claimed invention.

65. Below, I note specific prior art disclosure that satisfies each element of each challenged claim.

## **B. Claim 1**

66. Kim, Invisalign, and Salah, teach each and every element of claim 1, as I explain below.

### **1. Claim 1 preamble**

67. The preamble of claim 1 recites “[a] method for evaluating the shape of an orthodontic aligner worn by a patient, said method comprising the following steps.” Kim and Invisalign teach the preamble of claim 1.

68. Kim teaches evaluating an aligner by reviewing an image of the aligner currently worn by the patient, to determine whether the aligner is normal and appropriate. EX1005, ¶66. Invisalign teaches that evaluating a currently-worn clear aligner includes assessing the fit of the aligner, and that this assessment involves determining a distance between the teeth and the aligner when worn by

the patient, as depicted in two-dimensional photographs showing good and poor aligner seating. EX1006, 1. Kim and Invisalign also teach that the evaluation can determine that an aligner does not fit appropriately (for example, because the aligner may have been formed using a distorted impression of teeth). EX1006, 1; EX1005, ¶¶66-67. In view of Kim and Invisalign, a POSA would have understood that the shape of an orthodontic aligner can be assessed by analyzing images of the aligner worn on a patient's teeth, including by Invisalign's teachings to determine whether the image shows that the aligner is shaped appropriately to fit the patient's teeth based on their depiction in one or more images acquired by Kim's smartphone.

69. Kim and Invisalign thus teach the preamble of claim 1.

**2. Step 1(1)**

70. Step (1) of claim 1 recites as follows:

1) acquisition of at least one two-dimensional image of teeth of said patient, referred to as “updated image”, under actual acquisition conditions;

at least one updated image referred to as “aligner image”, at least partially representing the aligner in a service position in which it is worn by said teeth; and at least one updated image referred to as “dentition image”, identical to or different from the aligner image, representing said teeth,

As I addressed above in section VIII.A, step 1(1) indicates that the aligner and dentition images may be different or the same. In other words, this claim element may be satisfied by acquiring only a single image (that is, one two-dimensional image that the claim refers to as an “updated image”), representing both an aligner worn by a patient’s teeth and the patient’s teeth themselves. My analysis below focuses on this aspect of claim 1. As I discuss below, Kim, Invisalign, and Salah teach step 1(1).

71. Kim teaches that a patient’s smartphone or similar device may be used to acquire orthodontic treatment information. *See* EX1005, Abstract, ¶¶1 (“smartphone of an orthodontic patient”), 10 (“[A]n orthodontist may obtain accurate teeth alignment information using a device, e.g., a smartphone, of an orthodontic patient...”), 42 (“Herein, the orthodontic patient terminal 10 is not limited to a smartphone and may be one of all information devices capable of transmitting a teeth alignment information.”). This can include “using a camera” of the device to acquire photographs “showing a teeth alignment state of the orthodontic patient.” EX1005, ¶¶55-56. This can further include aligner information, and in particular may include “receiving the clear aligner information about a currently worn clear aligner,” enabling the orthodontist to “check[] a photo or a video of the clear aligner currently worn by the orthodontic patient.” Using this photo or video from the patient’s cellphone, the orthodontist “determines

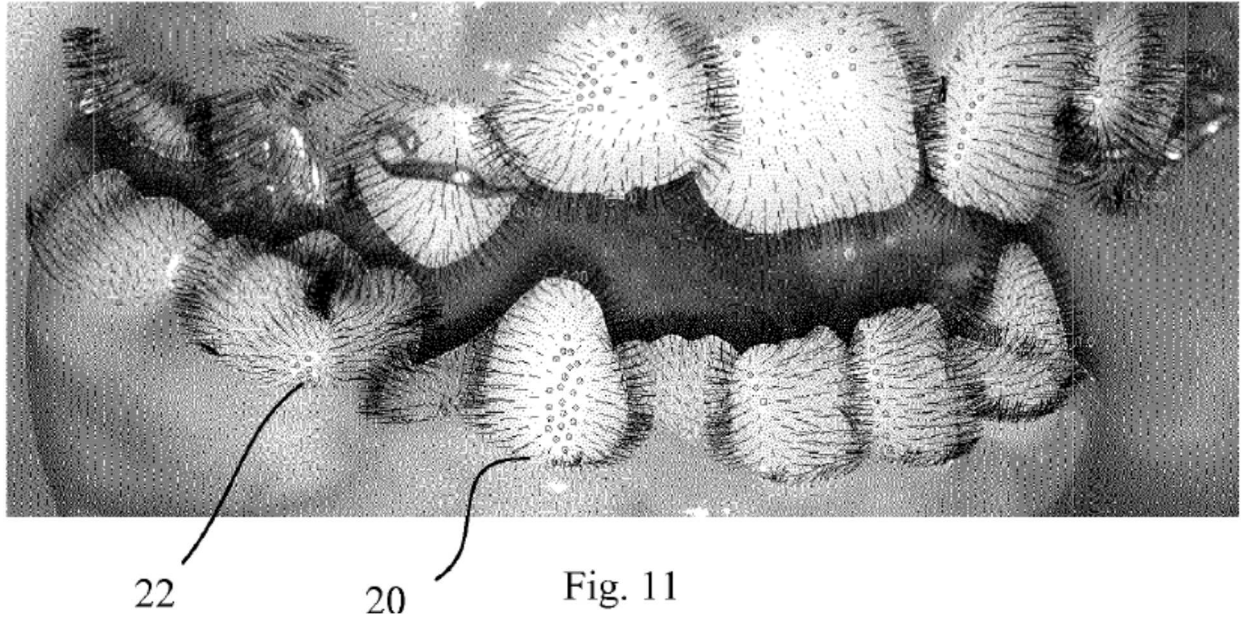
whether the clear aligner is normal and corresponds to an appropriate step”

EX1005, ¶66. Thus, Kim teaches acquiring an aligner and dentition image (i.e., an image depicting an aligner worn on a patient’s teeth) as recited in step 1(1).

72. Invisalign confirms that analyzing a two-dimensional image of an aligner in a service position as well as the patient’s teeth (such as a photo or video taken by a cellphone, as taught by Kim) can produce measurements useful for orthodontic assessment. Invisalign teaches that a large gap between a tooth and an aligner, such as a gap of more than 1 mm, indicates poor fit. EX1006, 1. Invisalign further illustrates that such a gap is visually distinguishable in a digital photograph of a patient’s teeth that at least partially represents an aligner worn in a service position on the teeth. *See id.* Accordingly, Invisalign provides a reason to acquire a two-dimensional image of the patient’s teeth with an aligner being worn in a service position: by assessing the gap visible between aligner and teeth, Invisalign teaches that it can be determined whether an aligner fits correctly (e.g., is normal and corresponds to an appropriate step), or whether it is seated or fit poorly. This assessment involves determining the size of the gap, with gaps above a given threshold (e.g., 1 mm) indicating a poor fit.

73. Salah similarly teaches acquiring two-dimensional dental images, including images of teeth fitted with orthodontic appliances. For example, Salah teaches that a user—which may be a non-specialist such as a patient or the

patient's relative—may acquire images of a patient's dentition using an image acquisition apparatus such as a mobile phone. EX1008, 31:4-7. The mobile phone can include a photographic or video camera. EX1008, 27:11-13 ("The image acquisition apparatus preferably comprises a camera or a video or infrared camera, which the user, e.g. the patient or one of their relatives, positions by means of a viewfinder or screen, before operating it"). Salah describes that the acquired images can include an "updated image." EX1008, 2:1-2 ("acquisition of at least one two-dimensional image of the patient's arches, the so-called 'updated image,' under actual acquisition conditions"). Salah also teaches that the image of the teeth may include an orthodontic appliance; for example, Fig. 11 (below) depicts a reference map generated from an image of teeth of a patient wearing an orthodontic appliance. EX1008, 64:7-12, Fig. 11 (showing teeth with orthodontic wires visible).



EX1008, Fig. 11. Thus, Salah also teaches acquiring two-dimensional images of a patient's teeth, including teeth of a patient using orthodontic appliances.

74. Acquiring a two-dimensional image depicting teeth wearing an aligner is also consistent with published methods of orthodontic practice. For example, a step-by-step guide for remote orthodontic monitoring published by Dr. Scott Frey no later than May 4, 2017, described how to instruct patients to acquire images for use in assessment of orthodontic treatment status, including taking images of "teeth apart and aligners out," "biting down with aligners removed," and "with teeth apart and aligners in." EX1009, 19. This guide confirms that acquiring digital photographs of patient's teeth, including patient-acquired cellphone images of teeth of patients wearing aligners in a service position, was known to be a useful practice for assessment of a patient's orthodontic treatment status.

75. Accordingly, Kim, Invisalign, and Salah teach step 1(1).

### **3. Step 1(2)**

76. Step (2) of claim 1 recites as follows:

2) if the dentition image is different from the aligner image, conversion of the dentition image so that it represents said teeth as seen under the acquisition conditions used during the acquisition of the aligner image in step 1);

77. Step 1(2) only applies “if the dentition image is different from the aligner image.” As I discussed above in section VIII.A, claim 1 does not require that the dentition and aligner images are different—it also encompasses embodiments in which the aligner and dentition images are a single, identical image. This alternative is also expressly recited in dependent claim 4. Claim 1 does not provide any alternative steps required if the two images are not different—i.e., if the “dentition image” and “aligner image” refer to the same image. As I discussed above, my analysis focuses on this alternative, in which there need only be a single image showing both the patient’s teeth and an aligner worn in a service position on those teeth. For this alternative, step 1(2) applies no required steps. Thus, the combination of Kim, Invisalign, and Salah satisfies step 1(2), since the combination teaches such an updated image in which the dentition and aligner images are not different.

#### 4. Step 1(3)

78. Step (3) of claim 1 recites as follows:

3) determination, by means of image processing software, for each of a plurality of teeth represented on the dentition and aligner images, of interior and exterior tooth outlines representing the outline of the free end of said tooth on the dentition and aligner images, respectively;

79. I have been instructed that this claim term should be interpreted to encompass the use of image processing software to perform a function of determining interior and exterior tooth outlines. This image processing software includes, for example, the software described at lines 10:28-11:34 of the '945 patent, or the similar image processing software taught by Salah (*see* EX1008, 34:15-36:14), which is also referred to by the '945 patent as teaching software for image processing including detecting outlines. EX1001, 7:26-62 ("All the features of steps c) to e) described in PCT/EP2015/074896 are applicable....Image processing makes it possible to extract and quantify the discriminating information....The discriminating information is preferably chosen from the group consisting of outline information...."); EX1008, cover (listing application number as PCT/EP2015/074896). I apply this interpretation in my discussion throughout this declaration.

80. As I discussed above for the previous claim elements, claim 1 encompasses an alternative in which the aligner and dentition images constitute

only a single image representing a dentition and an aligner, and it is to this alternative that I focus my analysis. For such an embodiment, step 1(3) is satisfied by determining “interior and exterior tooth outlines” for a plurality of teeth in that single image. As I further discussed above in section VIII.B, the recited “interior and exterior tooth outlines” correspond to lines delimiting the ends of teeth and a part of an aligner, respectively. In other words, step 1(3) is satisfied by detecting lines representing the free end of teeth and of corresponding edges of an aligner in an image depicting both. As I discuss below, Kim, Invisalign, and Salah teach step 1(3).

81. Salah teaches that dental images may be analyzed to detect “discriminant information,” which can include contours of objects depicted in the images, including teeth and other intraoral objects, such as gums. EX1008, 34:5-14, 55:21-56:7. A contour map of detected tooth edges showing the resulting outlines of teeth is shown in Fig. 6b, reproduced below.

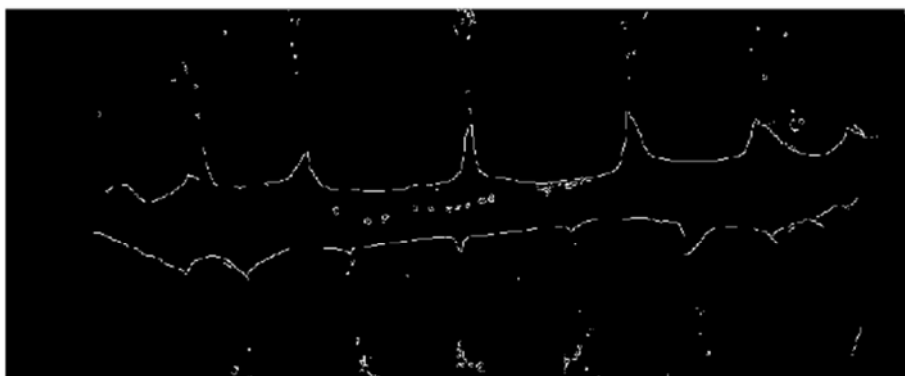


Fig. 6b

EX1008, 34:5-14, Fig. 6b. This includes outlines of the free ends of each of a plurality of teeth. *See* EX1008, 23:4-8, 34:6-7, Figs. 6a-6b (showing multiple teeth and their outlines). This discriminant information can be used to generate a “reference map representing the discriminant information,” and Salah provides an example of such a map generated for an image depicting teeth of a patient with an intraoral appliance. EX1008, 40:19-21, 64:7-8; *see id.*, Fig. 11 (reproduced above for element 1(1)).

82. Salah teaches that its contour detection may use “image processing software” employing any of a variety of known methods, which “can be used, for example, to detect high contrast regions and determine contours.” EX1008, 34:5-36:14. To detect “discriminant information” (e.g., “contour information”), Salah teaches a list of “well-known and preferred methods,” as well as other options that “can also be used.” EX1008, 34:5-36:14. The ’945 patent concedes that it was known to POSAs how to use image processing software to detect outlines and provides a list of generic image processing methods for outline determination that almost completely matches Salah’s list. *See* EX1001, 10:22-11:34 (listing image processing methods). Indeed, Salah provides a list of image processing methods with each “preferred” and “other” option being the same as the ’945 patent’s (with some minor differences in wording reflected in the translation of Salah into English), except that Salah also teaches that “Deepleraning” (a typo referring to

deep learning) may also be used, whereas the '945 patent omits this option. *See* EX1008, 34:11-36:14.

83. Applying the image processing approach taught by Salah to use image processing software to detect contours in an image representing a patient's teeth with an aligner worn in a service position on the teeth would result in detection of the edges of the depicted objects (teeth, aligner portions, etc.). This would include detecting both edges delineating the occlusal ends of each of a plurality of depicted teeth and edges delineating the tooth-shaped surfaces of the aligner corresponding to each tooth, which would constitute the recited interior and exterior tooth outlines. To illustrate what I mean by this, below I have provided an example edge detection that I generated based on the image from Invisalign using simple, long-known techniques. First, I show an image of teeth wearing an aligner in a service position, as shown in Invisalign. Then I have provided a second image showing the result of applying a simple Canny edge detection technique to the Invisalign image, combined with bilateral filtering for noise reduction, consistent with the teachings of Salah. *See* EX1008, 34:11-35:11 (teaching to use "application of well-known masks or filters provided by image processing software," including "a bilateral filter" and Canny edge detection). I have also added simple annotations indicating the locations of the edge of a tooth and the edge of a corresponding part of the aligner, as well as showing the separation between the two. As can be seen in both

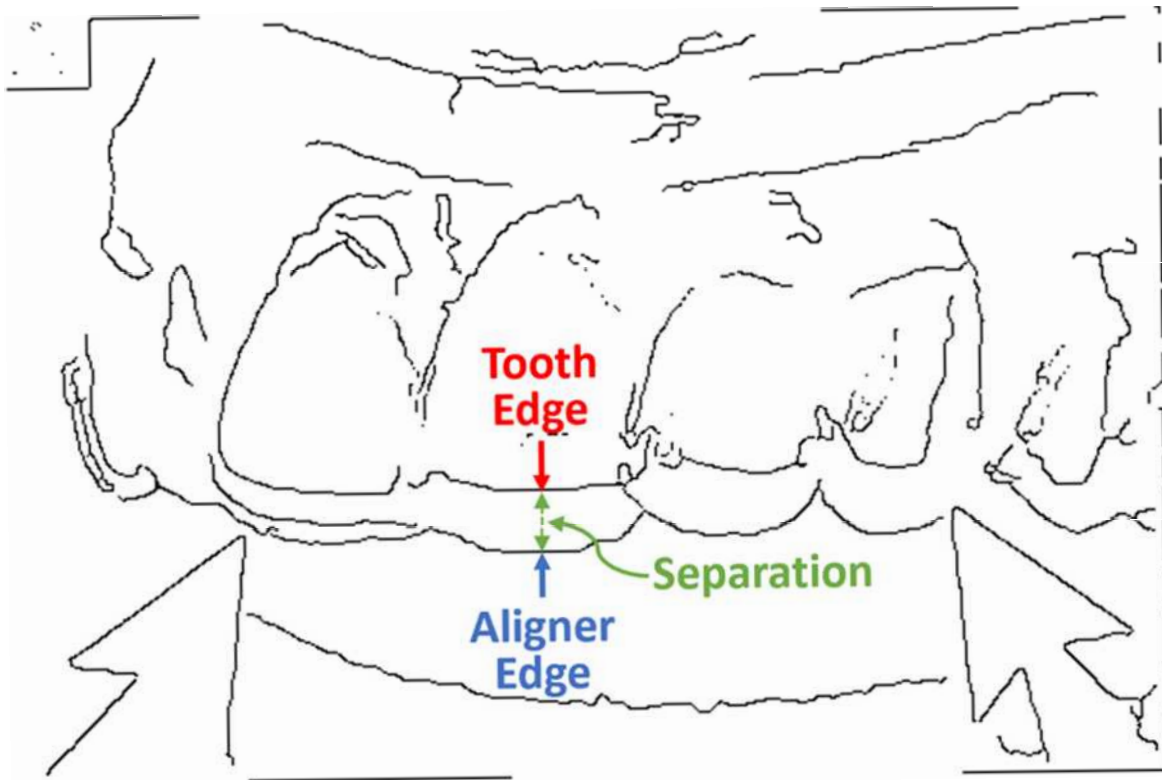
the original image and the simple edge detection version, separations are plainly visible for multiple teeth.

**Original Image:**



EX1006, 1.

### Simple Edge Detection:



To produce the above edge-detected figure, I used a Canny edge detector, which is an old, simple technique referred to by Salah as an available option that may be combined with any of a long list of other known techniques. EX1008, 34:16 (noting that one may “search for contours using Canny’s algorithm”). Canny edge detection produces a simple binary map, in which edge pixels have one value (e.g., 1) and all other pixels have a different value (e.g., 0). As I discussed above, it was also known that more advanced options for contour detection could go beyond mere detection of edges, and also provide specific identification of the objects found in different regions defined by the detected edges. Since the photographs of Kim, Salah, and Invisalign are ordinary camera images such as those acquired by a

cellphone, they show essentially the same thing a person would see when viewing teeth and an aligner in real life. The ability to see a gap and visually assess it in real life naturally maps over to the ability to detect and measure the same gap using computer vision techniques like Salah's various image processing software options for detecting objects and the contours defining the objects' edges, and applying such known methods of contour detection would produce contours in images like those discussed in Kim and Salah that corresponded to the free ends of teeth and the aligner depicted in such images.

84. As I explained above in section IX.A, a POSA would have been motivated in view of Kim and Invisalign to apply the contour-detection techniques of Salah to use image processing software to detect edges of teeth and aligners depicted in images of patient's teeth so that the assessment of gap between aligner and teeth could be made, as taught by Invisalign. This would include detecting outlines of each of a plurality of teeth and corresponding outlines of the aligner, such as the multiple teeth and matching aligner portions shown in Invisalign. *See* EX1006, 1 (showing arrows pointing to aligner surfaces separated from each of a plurality of teeth, indicating that distance from the aligner should be evaluated for each of a plurality of teeth). Because the detected edges of the aligner and teeth correspond to the edges of the physical objects depicted, a POSA would have understood that measuring the distance between the outlines of the teeth and the

aligner as detected by Salah's image processing software would allow determination of the gap between each tooth and the corresponding part of the aligner. The use of image processing software to determine outlines of the teeth and aligner as part of this process would constitute the determination "for each of a plurality of teeth represented on the dentition and aligner images, of interior and exterior tooth outlines representing the outline of the free end of said tooth on the dentition and aligner images," as recited in step 1(3).

85. In sum, Kim, Invisalign, and Salah, teach using image processing software to determine outlines of both a plurality of free ends of teeth (interior tooth outlines) and of the corresponding parts of the aligner (exterior tooth outlines) for the dentition and aligner images (an image depicting both teeth and worn aligner). Accordingly, Kim, Invisalign, and Salah teach step 1(3).

## **5. Step 1(4)**

86. Step (4) of claim 1 recites as follows:

4) comparison of the interior and exterior tooth outlines, so as to determine at least one score according to said comparison.

87. Step 1(4) requires comparing the interior and exterior outlines (outlines of teeth and aligner) so as to determine a score. As I explained above for step 1(1), Kim teaches checking "a photo or a video of the clear aligner currently worn by the orthodontic patient" to determine "whether the clear aligner is normal and corresponds to an appropriate step." EX1005, ¶66. As part of this assessment,

a POSA would have applied the teachings of Invisalign to assess the distance between the patient's teeth and the aligner. *See* EX1006, 1; *supra* section IX.B.2. And as I discussed for step 1(3), this assessment would involve measuring a distance between an outline of each tooth and the corresponding outline for the aligner, using the image processing software of Salah to detect each outline via contour detection. *See* EX1008, 34:11-36:14; *supra* section IX.B.4. This determination of distance involves a comparison of the two outlines, at least in that determining the distance from one outline to another compares the two (e.g., by comparing their respective locations to assess relative distance). The result of this comparison would produce at least one score. As one example, the at least one score would be one or more values indicating the distance from one or more teeth (e.g., all teeth) to the aligner. This score could be a direct measurement of the image (e.g., in terms of pixels), or it could be converted to metric measurements (such as millimeters). As another option, the score could be a value comparing the distance of one or more teeth from the aligner to a threshold as taught by Invisalign; for example, the score could indicate that the aligner fits well if the distance threshold was not exceeded and did not fit well if the distance threshold was exceeded. *See* EX1006, 1 (aligners not seating well if distance exceeds 1 mm). Indeed, Salah uses scores and thresholds in an analogous manner as part of its image analysis, confirming that the computational application of scores and

thresholds was known. *See* EX1008, Fig. 1, 40:22-41:18. A POSA would have found each of these options to be natural choices, alone or in combination, for generating scores to assess aligner fit based on the teachings of Kim, Invisalign, and Salah. Kim, Invisalign, and Salah thus teach step 1(4).

88. Accordingly, it is my opinion that claim 1 would have been obvious over Kim, Invisalign, and Salah.

### **C. Claim 2**

89. Claim 2 depends from claim 1, reciting “The method as claimed in claim 1, comprising, after step 4), the following step: 5) comparison of the score against an acceptability threshold and the emission of information according to the result of the comparison.” Kim, Invisalign, and Salah teach this step.

90. As I discussed above for claim 1, Invisalign teaches to use a threshold to assess aligner acceptability. For example, Invisalign teaches that when an aligner worn on a patient’s teeth has a tooth-aligner gap of less than 1 mm, “this is natural deflection that should occur so the Aligner can move the tooth,” whereas if the gap is greater than 1 mm, this means that the “Aligners are not seating well.” EX1006, 1. In view of this teaching, a POSA would have been motivated to compare a score as discussed above for claim 1 (e.g., a score reflecting a separation between teeth and aligner, as determined by assessing separation by the contours detected using Salah’s image processing software) to apply the acceptability

threshold taught by Invisalign, thereby determining that where the threshold is exceeded, the aligner is not seated well on the teeth, or conversely that where the threshold is not exceeded, the aligner is acceptably seated.

91. This assessment would be consistent with Kim’s teaching to “check[] a photo or a video of the clear aligner currently worn by the orthodontic patient, and determine[] whether the clear aligner is normal and corresponds to an appropriate step.” EX1005, ¶66. For example, if the result of applying Invisalign’s threshold assessment indicated that one or more teeth had excessive gaps, that would be an indication that the aligner was not normal or did not correspond to an appropriate step. EX1006, 1 (evaluation may indicate aligner has “excessive flash” or results from a “distorted impression” (meaning it was not normal)), 6 (lack of fit may indicate incorrect aligners or need for mid-course correction (meaning the aligner did not correspond to an appropriate step)).

92. A POSA would have understood that the threshold comparison could be implemented in multiple ways. As a simple example, the edge detection software could indicate the locations of the aligner and tooth edges, or the gap between (e.g., measured in pixels), and provide that information to the orthodontist to allow the orthodontist to make the judgment of whether the aligner was suitable by applying the threshold to the measured distance. As another option, the threshold taught by Invisalign would be applied computationally, by comparing the

measured aligner-tooth separation to the threshold. A POSA would have known that a conversion of a length threshold like 1 mm to a distance measurement in an image (e.g., in pixels) would be straightforward. For example, a known width (like the typical size of a tooth, or the known width of the patient's tooth, based on a model as taught by Salah) would permit a conversion of units using simple geometry. Further, Salah teaches that registration marks with known size and spacing can be included in the images, and these too would provide a straightforward calibration basis to convert image measurements in pixels to metric measurements in units of distance (e.g. millimeters). *See* EX1008, 38:7-9.

93. As I explain below, a POSA would also have found it obvious to emit information according to the result of the comparison recited in claim 2 (i.e., a comparison of the aligner's distance from teeth to the threshold), both as a matter of common sense and based on the specific teachings of the prior art. For example, it would have been obvious to send a message indicating that the aligner was or was not suitable based on the assessment, so that the patient (or treating orthodontist) would be aware of the result of the comparison. As a practical matter, it would have been common sense to emit information according to the results of any such comparison performed by a computer, since the purpose of performing evaluations of aligner fit is to inform the people involved in patient treatment, such as the orthodontist and the patient, about the results of the analysis.

94. Emitting such information would be consistent with the teachings of Kim and Invisalign. As one option, the comparison could be used to provide guidance to a patient about wearing the aligner. Invisalign teaches that poor fit (indicated by a tooth-aligner separation greater than 1 mm) may be due to “non-compliance,” i.e., the “patient not wearing Aligners long enough for [a] tooth to move.” EX1006, 1. In this case, the guide teaches that the patient should be told to extend wear time of the aligner, and that orthodontists should emphasize to the patient “never to dispose of their Aligners and instruct them that the Aligners should be fitting well at the end of the 2-week period.” *Id.* Emitting information (e.g., sending a message) reflecting this instruction would constitute the emission of information recited in claim 2.

95. For example, this information could be sent as a message to the patient’s mobile device. This option is taught by Kim, which teaches that a “teeth alignment guidance information transmission program” can send information from the orthodontist to the patient’s mobile device that “advises, for example, an appropriate step of a clear aligner to be currently worn by the orthodontic patient.” EX1005, ¶63; *see also id.*, ¶64 (“[T]he teeth alignment guidance information may include at least one of a clear aligner information about a clear aligner to be worn in a current step among a clear aligner set, a wearing time information about a wearing time of the clear aligner, a replacement information about replacement of

a part of or the whole clear aligner set, a clear aligner state information about the state of the clear aligner, a clear aligner usage guidance information....”). Sending a message to the patient in this manner, such as a message to extend aligner wear time, to not dispose of them, and that they should fit well within two weeks, would constitute “emission of information according to the result of the comparison” as recited in claim 2.

96. Accordingly, it is my opinion that claim 2 would have been obvious over Kim, Invisalign, and Salah.

#### **D. Claim 4**

97. Claim 4 depends from claim 1, reciting “The method as claimed in claim 1, in which the dentition and aligner images are the same image.” Claim 4 would have been obvious in view of Kim, Invisalign, and Salah.

98. As I discussed above for claim 1, my analysis focuses on the alternative mapping of that claim in which the dentition and aligner images are the same image. *See supra* sections IX.A, IX.B.2. This is precisely what is required for claim 4. Accordingly, my analysis for claim 1 above applies equally to claim 4. Thus, claim 4 would have been obvious over Kim, Invisalign, and Salah for the same reasons as I discussed above for claim 1.

#### **E. Claim 5**

99. Claim 5 depends from claim 1, reciting as follows:

for each of a plurality of teeth for which the interior and exterior tooth outlines have been determined;

i) determination of a distance between the interior and exterior tooth outlines;

ii) determination of a distance threshold, preferably using the distances determined in the immediately preceding step;

iii) for each of said teeth, determination of a distance score dependent on

the distance between the interior and exterior teeth outlines, and the distance threshold.

100. As I discuss below, Kim, Invisalign, and Salah teach each of these steps.

101. At the outset, claim 5 indicates that its steps are performed “for each of a plurality of teeth for which the interior and exterior tooth outlines have been determined.” This aspect is not labeled as a separate step; instead, it is a preface that characterizes the following steps labeled i-iii. A POSA would have been motivated to perform the steps of claim 5 for a plurality of teeth for which interior and exterior outlines would be determined, as I explain below.

102. Salah, for example, teaches determining outlines for a plurality of objects, including teeth. EX1008, 23:4-8 (using detected gingival margins to delimit teeth and “determine which parts of the initial reference model correspond to which teeth”), 34:6-7 (“For example, figure 6b is an updated tooth contour map obtained from the updated image of figure 6a.”), Figs. 6a (showing multiple teeth),

6b (showing contours of multiple teeth). An example of Salah's contours detected for multiple teeth is shown below in Fig. 6b:

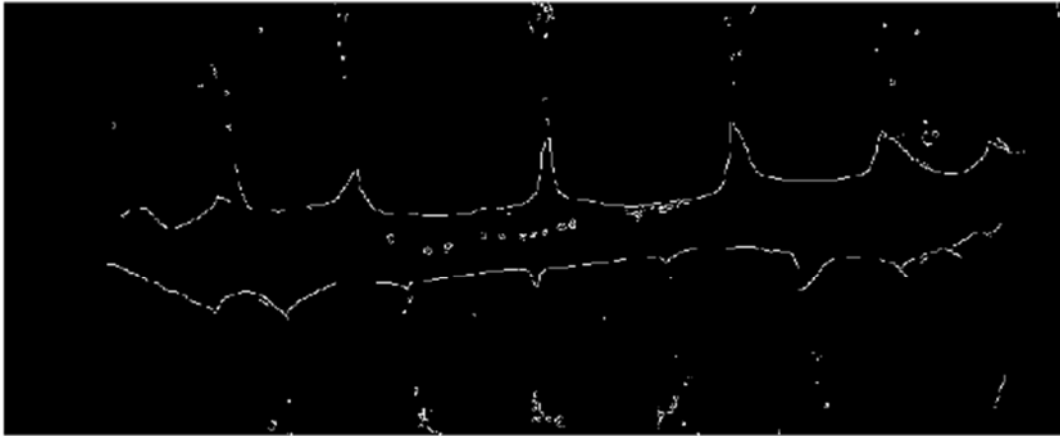


Fig. 6b

EX1008, Fig. 6b. As can plainly be seen in the above image, outlines of the free ends of each a plurality of teeth are detected.

103. Invisalign similarly provides reason to determine distances for each tooth for which interior and exterior outlines have been determined. For example, when indicating an assessment that an aligner is seated poorly, Invisalign includes arrows pointing at multiple teeth, as shown in the figure reproduced below:



EX1006, 1. As can be seen above, there are two arrow pointing at the surfaces of an aligner corresponding to distinct teeth also depicted on the image. Invisalign thus indicates applying its distance assessment to a plurality of teeth. Invisalign also urges that practitioners should “be tooth/teeth specific” when indicating necessary adjustments, and it includes a section handling “tooth-specific movements.” EX1006, iv, v (table of contents), 2 (cross-referencing to sections handling tooth-specific issues such as incomplete extrusions and unintended intrusions). In light of this disclosure, a POSA would have understood that the distance measurements disclosed by Invisalign applied to a plurality of teeth and the corresponding aligner surfaces for each tooth, not just a single tooth. Thus, when applying Invisalign’s teachings, a POSA would have measured the distances

and apply the threshold taught by Invisalign to produce scores for multiple teeth (e.g., each tooth for which distance was measurable in an image).

104. Thus, based on the teachings of Salah and Invisalign, a POSA would have concluded that outlines of multiple teeth and their corresponding parts of the aligner should be detected and that a distance assessment should be made for each such tooth. I discuss these measurements and assessments in more detail below.

### **1. Step 5(i)**

105. Step 5(i) recites “determination of a distance between the interior and exterior tooth outlines.” As I explained above for claim 1, this would have been obvious in view of Kim, Invisalign, and Salah. To briefly summarize what I discussed above, Salah teaches how to detect such outlines, using image processing software for contour or edge detection. EX1008, 34:11-36:14. Invisalign provides a reason to detect the outlines, because doing so would allow the determination of distances between teeth and aligners. *See* EX1006, 1. This measurement would enable judgement of whether the aligners are seated and fitting well. *See id.* This judgment would in turn inform Kim’s teaching to assess whether an appliance is normal and corresponds to an appropriate step of treatment. *See* EX1005, ¶66. Thus, Kim, Invisalign, and Salah teach step 5(i).

## 2. Step 5(ii)

106. Step 5(ii) recites “determination of a distance threshold, preferably using the distances determined in the immediately preceding step.” This step mentions that the determination may use the distances determined in step 5(i)—in particular, it says that the determination of the distance threshold “preferably” uses the distances determined in step 5(i). However, the claim does not indicate that the determination *must* use those distances. I understand that by indicating this as a preference rather than a requirement, the claim also encompasses determining a distance threshold in other ways, including ways that do not necessarily use the distances determined in step 5(i). Consistent with claim 5, the specification of the ’945 patent indicates that use of the distances to determine the threshold is a preferred option, but it does not rule out other options that do not use the distances to determine the threshold. *See* EX1001, 11:51-12:5. Among these options would be the determination of a threshold based on a predetermined value applicable for a particular type of measurement, such as a fixed threshold for measuring distances from teeth to aligners when assessing fit.

107. Invisalign teaches determination of a distance threshold. For example, Invisalign teaches using a distance threshold corresponding to a 1 mm gap between teeth and aligner, with distances under 1 mm indicating acceptable fit and distances over 1 mm indicating poor fit or poor seating. EX1006, 1. To apply such a distance

threshold to detected tooth and aligner outlines in the context of Kim and Salah, a POSA would determine a corresponding threshold reflecting the 1 mm threshold taught by Invisalign. This threshold could be determined, for example, simply by reading a value stored in memory for the threshold (e.g., reading a stored value of “1 mm”), so that the computing system can apply that read threshold value to each tooth’s measured distance from the aligner. *See, e.g.*, EX1008, 16:14-19 (storing code executable by computing device), 34:34:15-36:14 (using thresholds as part of image processing, including, for example, “applying a threshold to apply a fixed threshold to each element of a vector”).

108. Determining the threshold could also involve computationally adapting a distance threshold like the 1 mm value taught by Invisalign to the particular images analyzed in view of Kim and Salah. A POSA would have found it routine, when applying a 1 mm threshold to a distance within an image, to determine an appropriate distance scale to convert measurements made on the image itself to metric units. For example, distances in images would be measured in pixels, since as Salah recognizes, “[a]n image is made up of pixels.” EX1008, 18:6-7. Applying a threshold in millimeters would involve a simple conversion of scale (e.g., between millimeters and pixels). I discuss how this would be accomplished in further detail below when addressing claim 6. *See infra* section IX.F. Briefly, the determination of this scale conversion could be based on objects

in the image; for example, using the known size of teeth (e.g., based on known typical sizes or a reference model as taught by Salah, *see* EX1008, 20:15-21) or using registration marks with known separation, as taught by Salah. *See* EX1008, 38:7-9; *infra* section IX.F. Scaling images to determine the size of objects based on other imaged objects of known size would have been routine to the POSA. *See* EX1014, 125 (teaching that a “scale factor can be determined from one known reference length”); *see also id.*, 142-43 (using edge detection to identify lines for measurement). Adapting a threshold in metric units, such as millimeters, into units of distance in an image (e.g., pixel distance) would constitute determination of a distance threshold as recited in step 5(ii). Salah confirms that this kind of adaptive threshold was known to be applied in a similar context (image analysis when detecting contours). *See* EX1008, 34:34:15-36:14 (“applying an adaptive threshold to a vector” a known option for image analysis). The determination of a threshold from a defined metric threshold in conjunction with a measurement of a known length would be an analogous adaptation of a threshold in the context of length measurement, and would have been well within the skill of the POSA. *See also supra* section IX.C (discussing length thresholds for claim 2), *infra* section IX.F (discussing this conversion in the context of claim 6).

109. Accordingly, Kim, Invisalign, and Salah teach step 5(ii).

### 3. Step 5(iii)

110. Step 5(iii) recites “for each of said teeth, determination of a distance score dependent on the distance between the interior and exterior teeth outlines, and the distance threshold.” Kim, Invisalign, and Salah teach this step.

111. As I discussed above, Invisalign teaches that discrepancies of more than 1 mm between teeth and the aligner indicates that the aligner is not seating well. *Supra* sections IV.B, IX.A, IX.B.5, IX.C; EX1006, 1. As I also explained, a POSA would have applied Invisalign’s teachings to each of the recited teeth, in order to determine whether each of the patient’s teeth were appropriately fit by the aligner. *Supra* sections IX.B.4-5; *see* EX1006, 1 (showing arrows pointing toward each of a plurality of teeth-aligner separations). Making this assessment would be consistent with Kim’s teaching to determine whether the aligner was normal and corresponded to an appropriate step, since a bad fit indicates an abnormal or inappropriate aligner, while a good fit indicates the aligner is not abnormal or inappropriate by this measure. *See* EX1005, ¶65.

112. Applying this teaching to interior and exterior tooth outlines detected with Salah’s image processing software (*see* EX1008, 34:11-36:14) would be achieved by determining scores dependent on both the distance between those outlines and the distance threshold for each tooth. Since the threshold taught by Invisalign is a threshold beyond which an aligner is assessed to fit poorly,

distances below the threshold would be consistent with an acceptable fit and distances above the threshold would be consistent with a poor fit. This application of the threshold to the measured distance to score aligner fit for each tooth would thus meet the requirements of step 5(iii). Thus, Kim, Invisalign, and Salah teach step 5(iii).

113. Accordingly, it is my opinion that claim 5 would have been obvious over Kim, Invisalign, and Salah.

#### **F. Claim 6**

114. Claim 6 depends from claim 5, reciting “The method as claimed in claim 5, in which the distances are measured in pixels.” Kim, Invisalign, and Salah teach this element.

115. As I discussed above for claims 1 and 5, a POSA would have been motivated in view of Kim, Invisalign, and Salah to analyze digital images showing a patient’s teeth and an aligner worn in a service position, determine gaps between the aligner and teeth by detecting contours with image processing software, and measure distances between the resulting tooth and aligner outlines. *See supra* sections IX.A, IX.B.5. With regard to the measurement of distances within the digital images contemplated by the prior art, a POSA would have understood that such digital images would be composed of pixels. This is a natural aspect of digital images, which is taught specifically by Salah:

By “image” we mean a two-dimensional picture, such as a photograph.

An image is made up of pixels.

EX1008, 18:6-7. Salah also teaches that its contour maps are maps over pixels, noting that “contour information may be equal to 1 or 0, depending on whether a pixel belongs to a contour.” EX1008, 18:14-17; *see also id.*, 34:22-24 (identifying image processing steps based on areas measured in pixels and interpolation based on a pixel environment). Thus, Salah makes it clear that images are composed of pixels, and that properties within such images (e.g., lines like the contour lines taught by Salah) are also measurable in pixels.

116. Since the digital images being analyzed in the context of Kim, Invisalign, and Salah would be made up of pixels, and the contours detected within those images would be defined in terms of pixels, a POSA would naturally have measured distances between the contours within the images in pixels. And as I discussed above for claim 5, a POSA would not have any difficulty applying thresholds as taught by Invisalign using image measurements based on pixels. Indeed, it was well known how distances measured directly on images (e.g., in pixels) could be converted to distances measured in other units such as millimeters when analyzing the sizes of objects in an image. *See* EX1014, 125 (“scale factor can be determined from one known reference length”), Figs. 1, 5, 8, 10, 12-14 (showing various distance measurements via scaling and geometric transform).

117. With regard to determining a scale factor to apply a metric threshold to measurements in pixels, one option would be to use a known width, such as the typical size of a tooth, or the known width of the patient's tooth, based on a model as taught by Salah. *See* EX1008, 20:15-21 (initial reference model providing geometric tooth information accurate to 1/10 mm scale). This would permit a conversion of units using simple geometry. *See* EX1014, Abstract, 123-25 (teaching geometric assessment to measure distances in images). As another option, Salah teaches that registration marks with known size and spacing can be included in the images. *See* EX1008, 38:7-9. These registration marks would provide a straightforward calibration basis to convert between image measurements in pixels and metric measurements in units of distance (e.g. millimeters), because the known size and spacing of the registration marks would provide one or more known lengths from which to derive a scale factor for the depicted objects. Accordingly, a POSA would have found it routine to measure distances in pixels when applying Invisalign's teachings regarding tooth-aligner distances as measured based on contours of digital images as taught by Kim and Salah.

118. Thus, it is my opinion that claim 6 would have been obvious over Kim, Invisalign, and Salah.

119. For the reasons I have provided above, it is my opinion that each of claims 1-2 and 4-6 of the '945 patent would have been obvious over Kim, Invisalign, and Salah.

**X. CONCLUDING STATEMENTS**

120. In signing this declaration, I understand that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

121. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: October 31, 2023

By: /Hassan Foroosh, Ph.D./  
Hassan Foroosh, Ph.D.

## **XI. APPENDIX – LISTING OF CLAIMS**

1. A method for evaluating the shape of an orthodontic aligner worn by a patient, said method comprising the following steps:

1) acquisition of at least one two-dimensional image of teeth of said patient, referred to as “updated image”, under actual acquisition conditions;

at least one updated image referred to as “aligner image”, at least partially representing the aligner in a service position in which it is worn by said teeth; and at least one updated image referred to as “dentition image”, identical to or different from the aligner image, representing said teeth,

2) if the dentition image is different from the aligner image, conversion of the dentition image so that it represents said teeth as seen under the acquisition conditions used during the acquisition of the aligner image in step 1);

3) determination, by means of image processing software, for each of a plurality of teeth represented on the dentition and aligner images, of interior and exterior tooth outlines representing the outline of the free end of said tooth on the dentition and aligner images, respectively;

4) comparison of the interior and exterior tooth outlines, so as to determine at least one score according to said comparison.

2. The method as claimed in claim 1, comprising, after step 4), the following step:

5) comparison of the score against an acceptability threshold and the emission of information according to the result of the comparison.

4. The method as claimed in claim 1, in which the dentition and aligner images are the same image.

5. The method as claimed in claim 1, in which step 4) comprises the following steps:

for each of a plurality of teeth for which the interior and exterior tooth outlines have been determined;

i) determination of a distance between the interior and exterior tooth outlines;

- ii) determination of a distance threshold, preferably using the distances determined in the immediately preceding step;
  - iii) for each of said teeth, determination of a distance score dependent on
    - the distance between the interior and exterior teeth outlines, and
    - the distance threshold.
6. The method as claimed in claim 5, in which the distances are measured in pixels.

## XII. APPENDIX – EXHIBITS

| Exhibit No. | Description                                                                                                                                                                                                                                                                                                               |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1001        | U.S. Patent No. 11,109,945 to Salah et al.                                                                                                                                                                                                                                                                                |
| 1003        | Curriculum Vitae of Hassan Foroosh, Ph.D.                                                                                                                                                                                                                                                                                 |
| 1005        | U.S. Patent Pub. No. 2017/0281313 to Taewon Kim                                                                                                                                                                                                                                                                           |
| 1006        | Align Technology, Invisalign Clinical Monitoring Guide, (archived September 26, 2003 at <a href="http://web.archive.org/web/20030926024959/http://www.invisaligncec.com:80/consistent/pdfs/ICMG_Final.pdf">http://web.archive.org/web/20030926024959/http://www.invisaligncec.com:80/consistent/pdfs/ICMG_Final.pdf</a> ) |
| 1007        | Maninis et al., “Convolutional Oriented Boundaries: From Image Segmentation to High-Level Tasks,” <i>arXiv.org</i> (Apr. 28, 2017)                                                                                                                                                                                        |
| 1008        | Translation of PCT Pub. No. WO 2016066651 to Salah et al.                                                                                                                                                                                                                                                                 |
| 1009        | Scott Frey, Blog – The Ortho Cosmos, (archived May 4, 2017 at <a href="http://web.archive.org/web/20170504155213/http://theorthocosmos.com:80/blog">http://web.archive.org/web/20170504155213/http://theorthocosmos.com:80/blog</a> )                                                                                     |
| 1012        | PCT Pub. No. WO 2016066651 to Salah et al.                                                                                                                                                                                                                                                                                |
| 1014        | Criminisi et al., “Single View Metrology,” <i>International Journal of Computer Vision</i> 40(2) (2000)                                                                                                                                                                                                                   |
| 1015        | Krizhevsky et al., “ImageNet Classification with Deep Convolutional Neural Networks,” <i>Advances in Neural Information Processing Systems</i> 25 (2012)                                                                                                                                                                  |
| 1016        | Patrick Cavanaugh, “Visual Cognition,” <i>Vision Research</i> 51 (2011)                                                                                                                                                                                                                                                   |
| 1017        | Prasad et al., “Learning Class-specific Edges for Object Detection and Segmentation,” <i>Computer Vision, Graphics and Image Processing: 5th Indian Conference, ICVGIP 2006</i> (2006)                                                                                                                                    |