No. 26-1221

United States Court of Appeals for the Federal Circuit

DENSYS LTD.,
Plaintiff-Appellee,

v.

3SHAPE TRIOS A/S, 3SHAPE A/S,
Defendants-Appellants.

Appeals from the United States District Court for the Western District of Texas, No. 6:19-cv-00680-ADA, Judge Alan D. Albright

3SHAPE'S OPENING BRIEF (NON-CONFIDENTIAL VERSION)

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U.S. Patent No. 6,402,707 (Appx211-212, emphasis added)

1. A method for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising the steps of:

(a) *establishing an intra-oral fixed global registration position* inside the oral cavity of the dental patient, said intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, said global coordinate space is associated with a fixed global reference coordinate system, said global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity;

(b) providing *a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity*;

(c) selecting a field of view of said measuring and imaging device located at a global position in said global coordinate space of the oral cavity;

(d) acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in said selected field of view of said measuring and imaging device, and *recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position*, for forming at least one globally recorded three-dimensional measurement and image of the intra-oral objects and features located in the oral cavity;

(e) repeating step (c) and step (d) for a plurality of said global positions and a plurality of said fields of view of said measuring and imaging device, for forming a plurality of said globally recorded three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient; and

(f) registering local coordinate space pixel positions in each of said plurality of globally recorded three-dimensional measurements and images with corresponding global coordinate space pixel positions, for forming a plurality of the three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient which are registered relative to same said intra-oral fixed global registration position.

CERTIFICATE OF INTEREST

1. **Represented Entities (Fed. Cir. R. 47.4(a)(1)):** 3Shape TRIOS A/S, 3Shape A/S

2. **Real Party in Interest (Fed. Cir. R. 47.4(a)(2)):** N/A

3. **Parent Corporations and Stockholders (Fed. Cir. R. 47.4(a)(3)):** 3Shape Holding A/S

4. **Legal Representatives (Fed. Cir. R. 47.4(a)(4)):** Troutman Sanders Pepper Hamilton LLP, Troutman Pepper Locke LLP, Troutman Pepper Hamilton Sanders LLP, Desmarais LLP, Ciccarelli Law Firm, Holland & Knight LLP, Brittanee Petrik, Bryan J. Cannon, Ryan C Deck, Gwendolyn Tawresey, David J. Shaw, Goutam Patnaik, Frank Liu, Gregory Len, Kimberly Coghill, William D. Belanger, Kristie L. Butler, Massimo Ciccarelli, Bruce S. Sostek, Natalie Cooley Parker

5. **Related Cases (Fed. Cir. R. 47.5(a)).** Other than the originating case(s) for this case, are there related or prior cases that meet the criteria under Fed. Cir. R. 47.5(a)? No.

6. **Organizational Victims and Bankruptcy Cases (Fed. R. App. P. 26.1(b)-(c)):** N/A

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The non-confidential version of this brief does not contain redactions. The nonconfidential version of the addendum contains redactions to the district court's order denying 3Shape's Renewed Motion for Judgment as a Matter of Law.

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Note: All emphasis added unless otherwise indicated.

STATEMENT OF RELATED CASES

No other appeal from the proceedings below was previously before this or any other appellate court. Counsel for appellant are unaware of other pending proceedings that would directly affect or be directly affected by the Court's decision in this appeal.

JURISDICTIONAL STATEMENT

The district court had jurisdiction under 28 U.S.C. §§ 1331, 1338, 2201, and 2202. This court has jurisdiction because this is an appeal of a final district court judgment in a patent-related action. *See* 28 U.S.C. §§ 1291, 1295(a)(1).

The jury's verdict was entered on April 8, 2022. Appx65–71. The court entered final judgment on February 20, 2026. Appx195–197. The judgment ruled that 3Shape infringed Claims 1 and 37 of the '707 patent, that 3Shape induced others the infringe these claims, and that infringement of these claims was willful. Appx195–196. 3Shape timely appealed on March 20, 2026. Appx3577; *see* 28 U.S.C. § 2107; Fed. R. App. P. 4(a)(1)(A).

INTRODUCTION

This case ultimately involves a vacuous patent—means-plus-function claims, with no "means"—as well as a fundamental mismatch between the purely functional limitations of the asserted claims and the system developed by defendant 3Shape, one of the pioneers of digital 3D oral scanning.

Oral scanning technology has revolutionized dentistry and orthodontics, allowing the creation of accurate 3D models of a patient's teeth and gums without messy physical molds, with companies like 3Shape at the forefront of developing this technology. 3Shape's approach to building these 3D models is to use scanners to capture thousands of images inside the patient's mouth. Subsets of these images are grouped together to form a subscan. 3Shape's system uses innovative and highly accurate algorithms to identify overlapping regions between subscans and then, using those overlapping regions, stitch together the subscans (and their thousands of individual images) into a single cohesive model.

Densys sued 3Shape for allegedly infringing U.S. Patent No. 6,402,707, which claims a fundamentally different way of creating a 3D model of the teeth and gums. Rather than looking for overlapping regions within images, the '707 patent picks an arbitrary fixed global registration position within the mouth. As the claimed system captures images, it measures and records the location of the measuring and imaging device relative to that fixed position. The '707 patent then uses those

measured and recorded positions to transform the images into a 3D model. Despite these critical differences, a jury nonetheless found 3Shape infringed claims 1 and 37. That verdict rests on two erroneous claim constructions and is not supported by substantial evidence.

First and foremost, the asserted claims of the '707 patent are indefinite means-plus-function claims and therefore invalid. Both asserted claims require "a measuring and imaging device for measuring and imaging the intra-oral objects and features." This is a classic means-plus-function term. It uses a well-recognized nonce word—"device"—and identifies the function the device must perform without describing the device's structure or components. Adding the adjectives "measuring" and "imaging" before the word "device" does not fill in those missing structural details any more than reciting them as the function after the word "device." Despite Densys's arguments below, the dependent claims do not transform the "measuring and imaging device" into a structural limitation either. Those claims either just further recite functional "mechanisms" the measuring and imaging device employs, or claim that the device uses an undefined set of "standard components and mechanisms for said measuring and imaging"—neither can save the claimed "device" from means-plus-function status. The district court's failure to treat that term as a means-plus-function limitation at a minimum requires a remand and a new claim construction.

But the more fundamental problem for Densys is that the specification does not provide any corresponding structure for the functional "measuring and imaging device" term. Much like the dependent claims, the specification recites every conceivable functional approach to measuring and imaging—electro-mechanical, magneto-mechanical, and photo-acoustic—and says those approaches are accomplished in such mechanisms using standard components. But Densys provided no evidence that a skilled artisan would understand what those standard components for measuring and imaging intra-oral objects and features were in 2000, when Densys filed its patent application—roughly a decade before 3Shape and other early pioneers launched the first widely available 3D dental scanners. Even setting that aside, mapping a means-plus-function term to every known way of achieving the claimed function does not disclose adequate structure to avoid indefiniteness. Yet, as it did for virtually every other disputed claim term, the district court gave the "measuring and imaging device" its "plain and ordinary meaning" without any analysis or explanation.

Holding the asserted claims indefinite would resolve this entire appeal, but the district court also misconstrued two related terms relevant to infringement. Claim 1 requires "recording" the position of the measuring and imaging device "relative to" a "fixed global registration position." Claim 37 includes virtually the same limitation, but adds that the system must also "measur[e]" the measuring and

imaging device's position relative to the fixed position. Both terms require measuring the distance from fixed position to the device. Measuring distance is how you determine a device's position relative to a fixed point, just as you determine the relative position of two points on a line by measuring how far apart they are. *E.g.*, Appx204(10:14–22); Appx208(17:11–14, 17:35–44). The district court, however, held for unexplained reasons that the "[p]lain and ordinary meaning" applied "for both terms with no measurement of distance required." Appx39.

That construction is inconsistent with the language of the claims and the description of the invention in the specification. The word "measuring" is right there in claim 37, and the most relevant measurement between two positions is the distance between them. The surrounding claim language in both claims further confirms the purpose behind recording the measuring and imaging device's position is to take measurements. If that were not enough, the specification consistently describes the invention as "*measuring and determining distances* from intra-oral global registration position 28 to a measuring and imaging device." Appx205(15:58-62). This consistent description is a telling sign of what the claims require.

In any event, even under the district court's constructions, no substantial evidence supports the jury's verdict precisely because 3Shape's approach to scanning is fundamentally different from the measurements the claims require. The claims require "an intra-oral fixed global registration position inside the oral cavity."

But 3Shape's products have no need for a *fixed* global registration position because they use multiple local coordinate systems that *change over time*. Densys pointed to the center of mass of the *first subscan* as a fixed global position, but the center of mass is a temporary value used at the start of the scanning process and then discarded. It is not used as a reference point to determine where objects within *subsequent subscans* fit within a global coordinate space of the full mouth because it no longer exists.

There is likewise no substantial evidence that 3Shape willfully infringed the '707 patent. Showing dentists instructional videos explaining how to use a product is not willful infringement, especially when 3Shape had a good-faith belief the accused products do not infringe. After Densys sent 3Shape a generic notice letter in 2012—before any of the accused products were on the market—3Shape reviewed the patent and assessed how its claims would map onto 3Shape's approach. It determined its approach would not infringe because 3Shape does not rely on a global registration position. The jury (incorrectly) disagreed with that conclusion, but that does not make the conclusion unreasonable or 3Shape's conduct willful.

For any of these reasons, the judgment should be reversed.

STATEMENT OF ISSUES

1. Whether the term "measuring and imaging device for measuring and imaging" in claims 1 and 37 of the '707 patent (a) is a means-plus-function term and (b) is indefinite because it lacks any corresponding structure in the specification.

2. Whether the district court erroneously construed the "recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position" by holding that "no measurement of distance [is] required."

3. Whether substantial evidence supports the jury's verdict that 3Shape's accused products "establish[] an intra-oral fixed global registration position inside the oral cavity," where those products rely on a different technique that creates a complete 3D model by identifying overlapping regions within subscans rather than relying on a fixed global position.

4. Whether substantial evidence supports the jury's willfulness verdict, where the evidence showed Densys sent a generic notice letter in 2012—years before the accused products were on the market—with no claim charts and no infringement theory, 3Shape investigated Densys' allegations, and 3Shape reasonably concluded its products do not infringe because they do not use a fixed global registration position.

STATEMENT OF THE CASE

3Shape makes 3D dental imaging scanners. Densys, on the other hand, has never sold a functioning dental imaging product. *See* Appx1750-1751(185:25–186:11). In 2019, Densys sued 3Shape for patent infringement, alleging several versions of 3Shape's TRIOS scanners infringed U.S. Patent No. 6,402,707. After the district court gave almost every disputed claim term a "plain and ordinary meaning" construction, the case proceeded to trial. The jury found 3Shape directly and indirectly infringed claims 1 and 37—even though its products use a fundamentally different 3D scanning and imaging techniques than the claimed inventions—and awarded nearly $12 million in damages. Appx66–67, Appx69. The jury also found 3Shape's infringement was willful, despite its reasonable pre-suit investigation, and the district court four years later awarded $2.9 million in enhanced damages and $3 million in pre-judgment interest. Appx70; Appx196.

A. Background

This appeal is about dental scanning technology. Before the onset of digital scanning solutions, dental providers used molds to obtain an impression of a patient's teeth. Appx2164(599:1–8). After an impression was made, gypsum was poured onto the mold to get a stone model that would then go into a machine scanner. *Id.* These types of molds were traditionally used for dentures, implants, and braces.

Digital intraoral scanners that can create accurate 3D models of the teeth, mouth, and gums have largely replaced these physical molds.

These digital scanners work by using digital measuring and imaging techniques to take scans of a patient's mouth. "Measurements and images are defined in terms of global and local coordinates" within the mouth. Appx200(2:25–27). The local coordinates are specific to each individual image and specify locations and measurements within that image. Appx2338(773:4–9). The global coordinates provide a single set of coordinates that cover the entire mouth. *Id.* The process of mapping the local coordinates within each image to the corresponding global coordinates is known as registration. Appx200(2:31–41).

There are two well-known ways to perform this mapping or registration process. The first and most common method uses "overlapping scans." Appx2339(774:7–14). In this approach, the 3D scanner uses the local coordinates of the first image captured as the initial reference point for the global coordinate system. Appx2339(774:7–14). As the scanner captures a second image, it looks for overlap between the first and second images. Appx2339(774:7–14). Based on that overlap, the scanner can determine how to stitch the images together in the global coordinate space that has already been established for the first image. Appx2339–2340(774:7–775:3). By identifying the right global coordinates to stitch the two images together, the scanner learns how to translate the local coordinates to the

corresponding global coordinates. Appx2338–2340(773:10–775:3). The same process repeats for each subsequent image, where overlapping regions with the previously captured images are identified and the scanner uses those overlapping regions to stitch the new image into the global coordinate space. Appx2339–2340(774:7–775:3).

The second method is known as tracking-based registration. Appx2341(776:4–9). In this approach, the scanner establishes an arbitrary fixed point in the mouth and assigns that point a known position within the global coordinate space. Appx2341(776:10–14). As the scanner captures images, it records the location of its camera relative to that fixed position. *Id.* This approach does not require any overlap in the images. Because the scanner always knows the position of its camera relative to the arbitrary fixed point, the scanner can directly translate from local to global coordinates for each image independent of the overlap (or other relationship) between images. Appx2341–2342(776:25–777:16).

1. The ’707 Patent

The ’707 patent is directed to creating 3D measurements and images using a tracking-based registration approach. Appx198; Appx205(12:30–40). The device described in the ’707 patent first “establish[es] an intra-oral fixed global registration position inside the oral cavity of the dental patient.” Appx205(12:30–32). It then “record[s] the global position of the measuring and imaging device relative to the

intra-oral fixed global registration position" as it "acquires" a "three-dimensional measurement and image of the intra-oral objects and features located in the selected field of view," Appx209(20:31–39)—a process that repeats as different images are captured with different (not necessarily overlapping) fields of view inside a patient's mouth, Appx209(20:23–39). Figure 1 depicts the "intra-oral fixed global registration position [] 28" central to this measuring and imaging technique (outlined in blue below) and the global coordinate system (outlined in yellow).

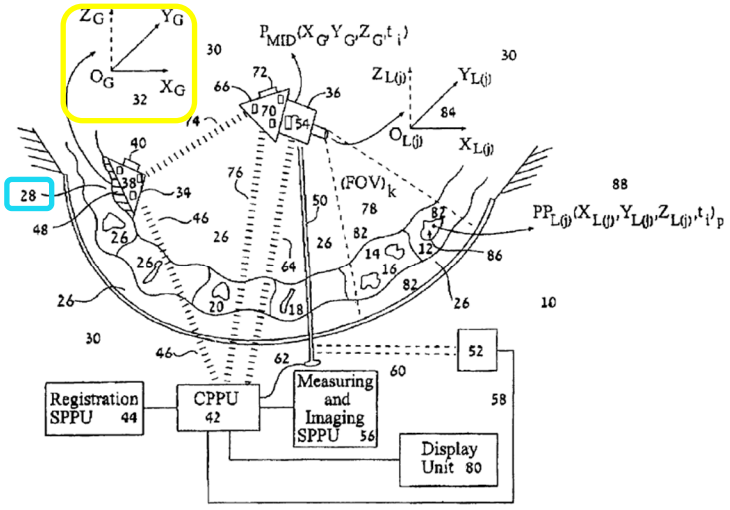


FIG.1

Appx199(Figure 1); Appx205(12:32–36).

Other portions of the specification describe the "intra-oral fixed global registration position" as one of the '707 patent's "aspects of novelty": "Different aspects of novelty of the present invention include, and are based on, the step of establishing an intra-oral *fixed global registration position* inside the oral cavity of a dental patient." Appx205(11:22–25). In case someone missed the purported importance of that fixed global registration position the first time, the specification

reiterates a few sentences later that "register[ing]" all the images "with respect to the same intra-oral fixed global registration position in global coordinate space" is "a significant aspect of the novelty here." Appx205(11:36–45). According to the '707 patent, "the prior art has no teaching of the establishment and use of *the same* intra-oral fixed global registration position … for the purpose of registering all local coordinate space pixel position of all" the acquired images. Appx205(11:46–52).

Given the perceived importance of the fixed global position, the '707 patent unsurprisingly disparages measurement techniques that instead rely on overlapping images. Appx211(23:62–24:10) (distinguishing the techniques of the '707 patent from prior art methods involving merging images, e.g., overlapping images, based on the latter's "propagation errors"). This "[commonly used] method for performing the registration procedure," in the view of the '707 patent, is inferior because "the measuring and imaging device" "must skillfully . . . be repositioned in the same field of view of each other particular set of intraoral objects and features being measured and imaged by an operator." Appx203(7:8–19); *see also* Appx1994(429:9–15). The named inventors of the '707 patent set out to invent a technique that did not require carefully capturing overlapping images.

Claim 1 of the '707 patent is illustrative of the claimed invention:

> **1.** A method for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising the steps of:

> (a) *establishing an intra-oral fixed global registration position inside the oral cavity of the dental patient*, said intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, said global coordinate space is associated with a fixed global reference coordinate system, said global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity;
>
> (b) *providing a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity*;
>
> (c) selecting a field of view of said measuring and imaging device located at a global position in said global coordinate space of the oral cavity;
>
> (d) acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in said selected field of view of said measuring and imaging device, and, *recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position*, for forming at least one globally recorded three-dimensional measurement and image of the intra-oral objects and features located in the oral cavity;
>
> (e) repeating step (c) and step (d) for a plurality of said global positions and a plurality of said fields of view of said measuring and imaging device, for forming a plurality of said globally recorded three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient; and
>
> (f) registering local coordinate space pixel positions in each of said plurality of globally recorded three-dimensional measurements and images with corresponding global coordinate Space pixel positions, for forming a plurality of the three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient which are registered relative to same said intra-oral fixed global registration position.

Appx211–212(24:30–25:7) (emphasis added). Claim 37 is basically the same, except it claims a system rather than a method. Appx214(29:39–59).

The ’707 patent is largely silent about the claimed “measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity.” Appx211(24:43–45). The specification refers to several types of general “mechanisms” that the measuring and imaging device may use to capture images, such as “electro-mechanical,” “electro-optical,” and “photo-acoustic mechanisms.” But the ’707 patent does not describe the structure of the measuring and imaging device or the components that it uses to actually capture the measurements and images beyond saying it uses “standard components and mechanisms.” *See* Appx207(15:9-16). What those supposedly standard components are is left unstated.

2. Accused Products

3Shape has been at the forefront of the transition to digital 3D oral scanning technology. Appx2167–2168(602:19–603:4). Like other 3D scanners, its TRIOS family of digital scanners create 3D models of a patient’s teeth through an imaging process that allows dental providers to take pictures of a three-dimensional object and combine those pictures together to create a 3D model. Appx2334– 2336(769:4–15; 770:24–771:7). Those images are captured by an intraoral scanner, which captures images of a 3D object such as a tooth from multiple positions that capture the entire object. Appx2334(769:9–15). Software on the scanner takes those

different images and combines them into a complete image of the tooth or other 3D object. Appx2334(769:16–21).

Unlike the '707 patent, 3Shape's TRIOS scanning system creates this complete 3D model using overlapping images to map the local coordinates within an image to the mouth-wide global coordinate space. Appx2351(786:10–2). The images are "stitch[ed]" together as they are captured to form a 3D model in the same way a panoramic picture uses the overlap between "neighboring images" to build the full panoramic view. Appx2166(601:25–602:5); Appx2351(786:7–25). Much like a panoramic picture, the TRIOS scanner does not use position tracking and does not record positions to build a full 3D model. Appx2166(601:17–23).

3Shape has offered multiple versions of its TRIOS scanners since it released the original TRIOS Standard Cart in 2011. Appx2350(785:5–7). The TRIOS Standard Cart remained the only version on the market until 2013, when 3Shape released a new scanner called the TRIOS Color that provided color models. Appx2350(785:8–9). 3Shape continued to roll out improved versions of its products over the years that were faster and added the ability to perform scans wirelessly. Appx2350(785:10–17). Densys did not accuse the original TRIOS Standard Cart of infringement but did accuse eighteen other 3Shape scanners released between 2013 and 2019. Appx1866(301:1–6).

B. Proceedings Below

In 2019, Densys sued 3Shape for patent infringement of two patents. Appx217. By the time the parties reached trial, only claims 1 and 37 of the '707 patent remained asserted. Appx65.

1. Claim Construction

In April 2022, the district court issued its claim construction order, construing almost every claim limitation as its plain and ordinary meaning with no explanation. Appx38–40. Relevant to this appeal are three of the court's constructions.

First, the asserted claims recite "a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity." Appx211(24:44–46); Appx214(29:52–55). During claim construction, 3Shape argued that this is a means-plus-function term subject to 35 U.S.C. § 112(f) that lacks any corresponding structure in the specification and is therefore indefinite. Densys disagreed and asked the court to give the term its plain and ordinary meaning without explaining what that plain and ordinary meaning is.

At the *Markman* hearing, the district court found that the claimed "measuring and imaging device" is a structural term not subject to Section 112(f). Appx1352(35:11–16). The court did not explain its decision, point to any structural descriptions in the specification, or elaborate on what structures a skilled artisan

would associate with a measuring and imaging device. It simply said the term carries its "[p]lain and ordinary meaning." Appx39; Appx2569(1004:1–3).

Second, the asserted claims recite "an intra-oral fixed global registration position inside the oral cavity." Appx211(24:35–36); Appx212(26:44–45). Ultimately, the court construed the term to mean "a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system." Appx38.

Third, claim 1 recites "recording said global position of said measuring and imaging device *relative to* said intra-oral fixed global registration position," and claim 37 recites "measuring and recording global positions and orientations of said measuring and imaging device *relative to* same said intra-oral fixed global registration position." Appx211(24:50–58); Appx214(29:56–59). 3Shape took the position that the claim language required recording the global position by measuring a distance from the fixed global registration position. Appx636; Appx858–860; Appx39 (3Shape asking the court to construe claim 1 as "recording the global position of the measuring and imaging device *measured from* the intra-oral fixed global registration position" and claim 37 as "measuring and recording global positions and orientations of the measuring and imaging device *measured from* the intra-oral fixed global registration position."). Indeed, measuring is the only method of determining the relative positions described in the patent.

Densys argued that the term should be given its plain and ordinary meaning. Appx1312–1313. And again, with no explanation, the district court agreed with Densys and concluded that the terms should be construed to have their "[p]lain and ordinary meaning . . . with no measurement of distance required." Appx39.

2. Trial

At trial, 3Shape's noninfringement expert, Dr. Parris Egbert, and Densys's infringement expert, Dr. Chandrajit Bajaj, presented testimony concerning 3Shape's TRIOS systems. Dr. Egbert, explained the functionality of 3Shape's scanners, as compared to the '707 patent's claimed functionality. Appx2352(787:11–15). Specifically, Dr. Egbert reviewed the patent, documentation from 3Shape, 3Shape's products, and the court's claim constructions to determine whether 3Shape infringed Densys's patent. Appx2331–2332(766:19–767:3). Dr. Egbert determined that 3Shape did not infringe the '707 patent because 3Shape's technology works in a fundamentally different way than the processes claimed in the '707 patent. Appx2352(787:11–15). As explained previously, 3Shape uses an "overlapping scan registration" process in its scanning to obtain a full 3D model of a scanned area. Appx2362(797:10–15). In contrast, the '707 patent claims a "tracking based registration" method, whereby a fixed position is established, and each picture is recorded relative to the fixed position. Appx2341(776:10–14). Dr. Bajaj concluded that 3Shape infringed the '707 patent because 3Shape's scanner uses a "center of

mass" in its images, which he determined to be a "fixed position" on which all subsequent images are based. Appx1883–1885(318:4–320:6). However, Dr. Egbert explained that 3Shape "decided to use the overlapping scan registration technique instead of tracking the position of the scanner." Appx2362(797:12–15). In his opinion, this meant that there was no "fixed global reference coordinate system," as claimed in the patent, and therefore 3Shape did not infringe. Appx2363–2364(798:23–799:1).

The jury's infringement verdict, however, was hamstrung by the court's claim constructions. For example, in view of the district court applying plain and ordinary meaning to the "measuring and imaging device for measuring and imaging" rather than section 112(f), neither expert applied the claims to the specific structure of 3Shape's dental scanner, focusing *only* on its functionality. Densys's attorney asked only about the two functional words: "So how do you know that these components are measuring?" and followed up with "And this almost seems silly to ask, but how do you know they're doing imaging?" Appx1891–1892(326:15–16, 327:21–22). These questions do not provide any information on the structure of 3Shape's device. The testimony elicited from these questions generally described the alleged functions of 3Shape's dental scanner but did not touch on its structure. Appx1891–1893(326:17–327:8, 327:23–328:1). As another example, because the district court determined that the term "recording . . . global position . . . relative to said intra-oral

fixed global registration position" should be construed by its "[p]lain and ordinary meaning . . . with no measurement of distance required," the jury was barred from considering the differences between the claims, which require determining relative positions by measuring, and 3Shape's TRIOS scanners, which do not measure relative to a fixed global registration position. Appx2569(1004:4–11). The jury's infringement verdict was, in both instances, contrary to the asserted claims as properly understood in light of the specification.

In addition to literal infringement, Densys argued that 3Shape willfully infringed the '707 patent based on a letter sent to 3Shape seven years before it filed its case. This letter (which did not relate to any of the accused products in this case), which Densys sent to 3Shape in March 2012, stated in its entirety: "Please take notice that in regard to the intra-oral scanner, 3Shape is infringing on the following patents of densys3D: US Patent – 6402707; Patent Applications – EP1296592, JP4502137, and IS153599." Appx3532. Based on this single sentence, Densys asserted in closing argument at trial that 3Shape "had an obligation" to talk "to a U.S. lawyer and [get] an opinion, a real opinion that considered U.S. law, considered how to interpret this patent and considered whether their product infringed." Appx2597(1032:19–33:4). At the time this letter was sent, 3Shape had one intra-oral scanner on the market, the TRIOS Standard Cart, which is not one of the accused products in this case. Appx1416. After this letter was received, 3Shape did not hear

from Densys again about alleged infringement of the '707 patent until it filed a complaint in this case in November 2019—7 years after the letter. Appx1415.

3. Post-Trial Rulings

After trial, 3Shape moved for renewed judgment as a matter of law on two issues relevant here. First, 3Shape argued there was no substantial evidence of literal infringement because the 3Shape TRIOS scanners do not "establish an intra-oral fixed global registration position." Appx158–160. And second, 3Shape argued there was no substantial evidence of willful infringement. Appx143–149; Appx1403; Appx3425–3428.

As relevant here, 3Shape argued in its renewed judgment as a matter of law briefs, that even under the court's claim construction of "intra-oral fixed global registration position," its TRIOS scanners did not meet this element of the asserted claim. Appx1423–1425. Densys argued that the center of mass of a first subscan met this limitation. Appx1882(317:7–13); Appx1938–1939 (373:11–374:8), but 3Shape explained that the "center of mass" cannot meet this element because it does not "relat[e to] multiple sets of three-dimensional data" as required by the district court's construction. Appx1423. The issue was that even though Densys argued the center of mass was supposed to meet this claim limitation, Densys's expert only testified that a different claim element—"a fixed global reference coordinate system," which the district court construed to mean the "origin point [that] is fixed at a single

location within the intra-oral cavity" —"relate[s to] multiple sets of three-dimensional data." Appx1424. 3Shape further explained that the center of mass is a temporary variable in TRIOS code—i.e., it is not fixed and therefore cannot be an "intra-oral *fixed* global registration position." Appx1424. "[I]t is not stored or used again in any respect." *Id.*

Yet the court disagreed with 3Shape, first by referring back to its claim construction order and concluding, "the Court's constructions do not mean that the origin of the coordinate system cannot be located at the same point as the fixed global registration position." Appx159. Second, "the Court agrees with Plaintiff that the 'fixed registration position as the origin of the coordinate system is the most natural place for it [.]'" Appx160. The court did not address 3Shape's argument that the "center of mass" is not used to relate "multiple sets of three-dimensional data," as required by the asserted claims.

As to willful infringement, 3Shape argued there is no substantial evidence that 3Shape willfully infringed the '707 patent. The March 2012 notice letter, which was Densys's only evidence of willful infringement presented at trial, did not relate to any of the accused products in this case and was sent more than seven years before Densys filed suit. 3Shape further explained that after it received the notice letter, it had conducted an investigation of its intra-oral scanner and determined that it did not infringe because the TRIOS scanner did not include "a fixed global registration

position" as required by the claims of the '707 patent. Appx1417 (citing Appx2326(761:1–19 (discussing Appx3521–3530(DTX-084))); Appx2174–2175(609:14–610:4 (discussing Appx3516–3520(DTX-081))); Appx2189–2192(624:25–627:7 (discussing Appx3532(PX-32))); Appx2206–2207(641:6–20; 642:19–23).

In just one sentence, the court—treating both inducement and willfulness together—determined that certain 3Shape videos demonstrating how to use 3Shape's scanners, Appx3531; Appx3576, and not the notice letter, were evidence of intent for both types of infringement:

> With respect to whether there is substantial evidence for the jury to conclude that Defendants induced infringement or willfully infringed, the Court agrees with Plaintiff that there was, e.g., instructional videos, Defendants confirmed their intent to get dentists to use the Accused Products in accordance with the video, Defendants' expert testified that following the video's instructions would result in the origin point of the fixed global reference coordinate system being fixed at a single location within the intra-oral cavity, etc.

Appx148 (citations omitted).

The court further concluded that substantial evidence supported the jury's verdict "that Defendants did not have a reasonable belief that they did not infringe" based on the incorrect conclusion that "Defendants viewed the alleged patent infringement as relatively minor, Defendants did not review the accused source code, etc." Appx148 (citations omitted).

This appeal follows.

SUMMARY OF ARGUMENT

The Court should reverse the judgment below.

I. The asserted claims are indefinite. Both claims require "a measuring and imaging device for measuring and imaging the intra-oral objects and features." This is a classic means-plus-function term. "Device" is a well-recognized nonce word that derives meaning solely from its associated function, and the modifier "measuring and imaging" simply restates the claimed function rather than describing any structural detail. The dependent claims fare no better: they add that the device uses one of fourteen "mechanisms" of action, but mechanisms of action describe function, not structure. The district court erred by treating "a measuring and imaging device" as a structural term that carries its plain an ordinary meaning. Correctly construing that term as a means-plus-function limitation at minimum requires a remand for a new trial under a proper construction.

But no remand is necessary or appropriate because the specification contains no corresponding structure for that functional limitation, rendering the claims indefinite. The specification identifies every conceivable approach to accomplishing the claimed functions—from electro-mechanical to photo-acoustic "mechanisms"—and then says the device uses "standard components." But Densys presented no evidence that a skilled artisan would understand what the "standard components" for measuring and imaging intra-oral objects were in 2000, when the patent was

filed; 3Shape and other pioneers did not launch widely available 3D dental scanners until a decade later. In any event, claiming any (purportedly) standard arrangement of components and mechanisms for performing the claimed function is the antithesis of a structural limitation. Without any corresponding structure, the asserted claims are invalid. That should be the end of the appeal and this case.

II. Even if the claims were definite, however, the district court misconstrued two related terms relevant to infringement. Both asserted claims require recording the position of the measuring and imaging device "relative to" a fixed global registration position; claim 37 adds that the system must "measur[e]" those positions. The most natural way to determine a position relative to a fixed point is to measure the distance from that point, and the specification consistently describes the invention as "measuring and determining distances" from the fixed registration position to the measuring device. Appx205(12:58–62). The district court nonetheless held—again without analysis—that the "plain and ordinary meaning" applies "with no measurement of distance required." Appx39. That error distorted the infringement trial by instructing the jury to disregard a critical distinction between the '707 patent's claimed approach and 3Shape's fundamentally different technology.

III. The infringement verdict also fails for lack of substantial evidence. The '707 patent's claimed invention centers on establishing a fixed global registration position inside the oral cavity and recording the measuring device's position relative to that

fixed point. 3Shape's TRIOS scanners do not establish any such position, because they use a fundamentally different approach. Rather than rely on a single fixed position, they implement an "overlapping scan" approach, where consecutive subscans overlap with one another and software identifies those overlapping regions to stitch the subscans together. That approach uses multiple local coordinate systems that change over time—not a single fixed global position. To fill this gap, Densys argued that the "center of mass" of the first subscan satisfies the fixed global registration position limitation. But that center of mass is a temporary variable used at the start of scanning and then discarded—it is not fixed, it is not stored, and it is not used to relate subsequent scans to a global coordinate system. No reasonable jury could find infringement on this record.

IV. Finally, there is no substantial evidence of willful infringement. Willfulness requires deliberate or intentional infringement—knowledge of the patent is necessary but not sufficient. Densys presented no evidence that 3Shape deliberately infringed. Instead, the only pre-suit notice of the asserted patent that Densys identified was a single-sentence notice letter it sent in March 2012—seven years before it filed suit, predating every accused product in this case—i.e., the accused products did not even exist when the letter was sent. Further, that letter did not even identify any of the accused products, did not provide claim charts, and did not explain any infringement theory. After receiving the letter, 3Shape investigated the

patent and reasonably concluded that its products did not infringe because they do not use a fixed global registration position. Densys's only other evidence consists of routine product-use videos that 3Shape shared with dentists demonstrating how to use its scanners do not mention the patent. Neither the letter nor the videos establish the deliberate wrongdoing required for willfulness.

STANDARD OF REVIEW

A district court's claim construction, including identification of corresponding structure for a means-plus-function claim, is a legal question reviewed de novo when it is based solely on "evidence intrinsic to the patent." *Teva Pharms. USA, Inc. v. Sandoz, Inc.*, 574 U.S. 318, 331 (2015); *Williamson v. Citrix Online, LLC*, 792 F.3d 1339, 1346 (Fed. Cir. 2015) *(en banc)*; *AllVoice Computing PLC v. Nuance Commc'ns, Inc.*, 504 F.3d 1236, 1240–41 (Fed. Cir. 2007). This Court "review[s] indefiniteness determinations de novo." *HZNP Meds. LLC v. Actavis Lab'ys UT, Inc.*, 940 F.3d 680, 688 (Fed. Cir. 2019) (citing *Interval Licensing LLC v. AOL, Inc.*, 766 F.3d 1364, 1370 (Fed. Cir. 2014)).

Denials of motions for judgment as a matter of law are "reviewed under the law of the regional circuit in which the appeal from the district court would usually lie." *ACCO Brands, Inc. v. ABA Locks Mfrs. Co.*, 501 F.3d 1307, 1311 (Fed. Cir. 2007) (quoting *Summit Tech. Inc. v. Nidek Co.*, 363 F.3d 1219, 1223 (Fed. Cir. 2004)). "In the Fifth Circuit, the Court of Appeals 'uses the same standard to review

the verdict that the district court used in first passing on the motion.'" *Id.* (quoting *Hiltgen v. Sumrall*, 47 F.3d 695, 699 (5th Cir. 1995)). "A jury verdict must be upheld unless 'there is no legally sufficient evidentiary basis for a reasonable jury to find' as the jury did." *Id.* (citation omitted). "A determination of infringement is a question of fact that is reviewed for substantial evidence when tried to a jury." *Id.* (citation omitted). "Whether infringement is willful is a question of fact, and the jury's determination as to willfulness is therefore reviewable under the substantial evidence standard." *Id.* (quoting *Braun Inc. v. Dynamics Corp. of Am.*, 975 F.2d 815, 822 (Fed. Cir. 1992)).

ARGUMENT

I. THE "MEASURING AND IMAGING DEVICE" TERM IS AN INDEFINITE MEANS-PLUS-FUNCTION LIMITATION WITH NO CORRESPONDING STRUCTURE

Each of the asserted claims requires a "measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity." Appx['707; 24:30–25:7, 29:39–59]. This is a textbook means-plus-function claim term. "Device" is a classic nonce word that derives meaning exclusively from its associated function. *See Williamson*, 792 F.3d at 1350. And adding the adjectives "measuring and imaging" before the word "device" does not impose any meaningful structural constraints on the claimed device; it simply reiterates the claimed function. The problem for Densys is that the specification contains no corresponding structure, and thus the term is indefinite.

The district court, however, incorrectly concluded that the "measuring and imaging device" term is a structural limitation not subject to Section 112(f)'s requirements. Appx39. The court offered no analysis explaining its conclusion and did not identify the structural features of such a device. Appx1352(35:11–16). It instead gave the term its "[p]lain and ordinary meaning" without articulating what that meaning might be. Appx39. *There is no plain and ordinary meaning*. A measuring and imaging device has no well-understood meaning in the art, and neither the dependent claims nor the specification supply sufficient structure for the term. Indeed, Densys did not identify any evidence that the term possessed a well-understood meaning to a skilled artisan. The Court should therefore reverse and hold the asserted claims invalid.

A. A "Measuring And Imaging Device" Is A Means-Plus-Function Term

1. The Claims Define The "Measuring And Imaging Device" In Functional Terms

The "measuring and imaging device" term in claims 1 and 37 is a means-plus function limitation subject to 35 U.S.C. § 112(f). Means-plus-function terms "recit[e] a function to be performed rather than [] reciting structure or materials for performing that function." *Northrop Grumman Corp. v. Intel Corp.*, 325 F.3d 1346, 1350 (Fed. Cir. 2003); 35 U.S.C. § 112(f). Determining whether a term is a means-plus-function limitation requires construing the claim "to decide if it connotes

'sufficiently definite structure' to a person of ordinary skill in the art." *Apple Inc. v. Motorola, Inc.*, 757 F.3d 1286, 1296 (Fed. Cir. 2014).

The "measuring and imaging device" term does not have the necessary structural connotations. For starters, it contains the nonce word "device." And no witness testified that a skilled artisan would understand what a "measuring and imaging device" was in 2000. Appx574–578; Appx913–916; Appx1077. While there is a rebuttable presumption that Section 112(f) does not apply if the word "means" does not appear in the claims, "means" is not the only indicator that a term is written in means-plus-function style. *See Williamson*, 792 F.3d at 1348. The claim limitation can use a similar "nonce word that can operate as a substitute for 'means' in the context of § 112, para. 6." *MTD Prods. Inc. v. Iancu*, 933 F.3d 1336, 1341 (Fed. Cir. 2019) (quoting *Williamson*, 792 F.3d at 1350). Indeed, this Court confirmed in *Williamson* that "device" is a "[g]eneric" nonce word, "reflect[ing] nothing more than [a] verbal construct[] . . . that is tantamount to using the word 'means.'" *Williamson*, 792 F.3d at 1350; *see also* M.P.E.P. § 2181 at I.A (explaining that "device for" is a "non-structural generic placeholder[] that may invoke 35 U.S.C. 112(f)"). Like the term "means," it sets forth a "black box recitation of structure." *Williamson*, 792 F.3d at 1350. The use of the term "device" alone is thus a strong indicator that "measuring and imaging device" is a means-plus-function term.

The words that follow the "device" term are another significant clue. The language in claims 1 and 37 recite "a measuring and imaging device *for measuring and imaging* the intra-oral objects and features." Appx211(24:29–46); Appx214(29:52–53). This phrasing is another hallmark of means-plus-function terms, which define the claimed device by the function it performs. *Seal-Flex, Inc. v. Athletic Track and Court Const.*, 172 F.3d 836, 849 (Fed. Cir. 1999) (Rader, J., concurring). It spells out what the device is "for"—the functionality that the device provides—rather than the device's structural features.

It makes no difference that the claims require a "measuring and imaging device" rather than a bare device standing alone. The "measuring and imaging" adjectives simply reiterate the claimed functionality that the device must perform by repeating that the claimed device is "a *measuring and imaging* device for *measuring and imaging*." Appx211(24:44-46); Appx214(29:52–53). This is a tautology—a device for measuring and imaging is by definition a measuring and imaging device—rather than a meaningful structural constraint or a reference to a specific type of device with well-known structural features. *See Abiomed Inc. v. Maquet Cardiovascular LLC*, 2026 WL 346501, at *6 (Fed. Cir. Feb. 9, 2026) (holding "guide mechanism" is a means-plus-function term, with "mechanism" being a nonce term and "guide" a "functional modifier"). Repeating the claimed functionality does

not make it any less functional. *See Kyocera Senco Indus. Tools Inc. v. Int'l Trade Comm'n*, 22 F.4th 1369, 1380 (Fed. Cir. 2022).

The other limitations in claims 1 and 37 do not supply the missing structure. Claim 1 merely requires "locat[ing]" the device "at a global position in [a] global coordinate space," "selecting a field of view" for the device, "acquiring at least one three-dimensional measurement and image" within that field of view, and repeating the process for multiple "fields of view." Appx211–212(24:30–25:7). Claim 37 says even less. It requires that the device provide measurements and images "relative to [a] fixed global registration position," but otherwise puts no restraints on how the measuring and imaging device operates or is used. Appx214(29:39–59). Nothing in those claims provides any clue about the structure of the imaging and measuring device. The components the device uses to capture the required measurements and images, how those components are organized structurally, and how those components interact with one another remain a black box.

The dependent claims and the specification further confirm the claimed measuring and imaging device is not a structural limitation. Dependent claims 17 and 53 provide that the "measuring and imaging device" includes "standard components and mechanisms for said measuring and imaging the intra-oral objects and features located in the oral cavity." Appx212(26:47–51); Appx215(31:27-31). In the specification, the patent similarly describes a "measuring and imaging device"

that relies on "the variety of standard components and mechanisms for enabling measuring, imaging, and mapping[] intra-oral objects and features." Appx207(15:9–16). That is the opposite of using the "measuring and imaging device" term as "the name of a sufficiently definite structure." *Williamson*, 792 F.3d at 1351. It reflects an intent to claim any possible structural arrangement using an undefined universe of standard components and mechanisms.

Indeed, claiming any "standard" arrangement of "components and mechanisms" for performing a claimed function is just another way to define the claim element by the function it performs. It imposes no structural constraints, and if anything, strongly suggests there are no constraints. After all, if the dependent claims cover all standard components and mechanisms, then claim differentiation principles imply the independent claim must also cover non-standard components and mechanisms.

The "measuring and imaging device" term here is thus akin to the means-plus-function limitation in *Kyocera,* 22 F.4th at 1380–81. The claims there included a "lifter member," which this Court held "does not connote structure." *Id.* at 1380. Much like the measuring and imaging device here, "[i]t is a non-structural generic placeholder (member) modified by functional language (lifter)." *Id.* And, again like the claims here, the surrounding claim language did not "describe any structural detail about" how the lifter member performed the claimed function, while the

specification did not define the term. *Id.* at 1380–81; *Mas-Hamilton Grp. v. LaGard, Inc.*, 156 F.3d 1206, 1215–16 (Fed. Cir. 1998) (holding a "movable link member" is a means-plus-function term for similar reasons). The claims instead treat the measuring and imaging device as a functional placeholder.

2. Densys's Counterarguments Cannot Transform The "Measuring And Imaging Device" Into A Structural Limitation

Although the district court did not explain its decision, Densys offered several arguments below for why the claimed measuring and imaging device is a structural claim limitation. Rather than argue that a measuring and imaging device is a well-known term that skilled artisans associate with specific structural features, Densys pointed to the dependent claims. It asserted those claims "imbue the term 'measuring and imaging device' with copious structural elements." Appx913. But none of those claims recite any specific structures for carrying out the claimed function of measuring and imaging the intra-oral objects and features.

Start with claims 18 and 54. Those claims add that the "measuring and imaging device is designed, configured, and operates according to" one of fourteen different "*mechanisms* used for three-dimensionally measuring and imaging [] objects and features" or any "combination mechanisms thereof." Appx213(27:1–12); Appx215(31:48–60). Examples include "electronic mechanisms," "magneto-mechanical mechanisms," and "photo-acoustic mechanisms." *Id.* None of those

fourteen claimed mechanisms impart sufficient detail about the components or structure of the measuring and imaging device. They describe the mechanism of action the measuring and imaging device uses—not its structural components—in the same way as a claim that covers "means for measuring and imaging" using one of the fourteen listed mechanisms. Put another way, a mechanism of action like those in claims 18 and 54 describes how the measuring and imaging device operates, not what the measuring and imaging device is. That is why "mechanism" is a well-recognized nonce word. *See Williamson*, 792 F.3d at 1350.

The same is true for claims 19, 20, 55, and 56. Appx213(27:13–26); Appx215(31:61–32:7). Each of those claims provides that the measuring and imaging device must use specific "electro-optical measuring and imaging techniques." Those claims may limit the universe of claimed functionality, but they do not describe what the components of the device must be or how those components interact to create intra-oral measurements and images.

That leaves claims 17 and 53. Densys did not address the recited "standard components and mechanisms" in those claims but rather pointed to the separately claimed "position and orientation guide," "optional position and orientation guide automatic controller" and "local measuring and imaging programming and processing unit." Appx212(26:46–67); Appx215(31:26–47). Each of those elements are themselves means-plus-function terms in a standard "claim element for

performing function" format that use common nonce words like "controller," "unit," and "guide." *See, e.g.*, *Fiber, LLC v. Ciena Corp.*, 792 Fed. App'x 789, 791, 794–95 (Fed. Cir. 2019) ("control"); *Intelligent Automation Design, LLC v. Zimmer Biomet CMF & Thoracic, LLC*, 799 Fed. App'x 847, 851 (Fed. Cir. 2020) ("control circuit" was a means-plus-function term); *Dionex Softron GmbH v. Agilent Techs., Inc.*, 811 Fed. App'x 630, 632 (Fed. Cir. 2020) ("control unit"); *Diebold Nixdorf, Inc. v. Int'l Trade Comm'n*, 899 F.3d 1291, 1297 (Fed. Cir. 2018) (finding that "cheque standby unit" is means-plus-function term); *see also Paragon Films, Inc. v. Berry Glob., Inc.*, 2022 WL 1157506, at *6 (W.D. Tenn. Apr. 19, 2022) (finding that "folding guide" is subject to § 112 ¶ 6 as a term that "recit[es] a function to be performed rather than [ ] reciting structure for performing that function.").

Even if those terms were structural, they would not describe the structure used *to perform the claimed function* of measuring and imaging the intra-oral objects and features. That is evident from the language of claims 17 and 53, which state that function is carried out by separate, unspecified "standard components and mechanisms." Appx212(26:49–51); Appx215(31:29–31). The position and orientation guide is directed to a different function of "maneuvering, guiding, positioning, and orienting [the] measuring and imaging device"—not capturing measurements and images of the intra-oral objects and features. Appx212(26:52–57); Appx215(31:32–37); Appx863; Appx880(¶ 16). The automatic controller

simply directs the positioning guide. Appx212(26:58–60); Appx215(31:38–40). As for the local measuring and imaging programming and processing unit, it dictates when to capture the measurements and images and processes the resulting data. Appx212(26:61–67); Appx215(31:41–47). Like the other elements Densys relied on in the district court, it does not provide any structural details about the components that actually capture the images and measurements.

But that is the only structure that matters for purposes of determining whether the claimed measuring and imaging device is a means-plus-function element. *See Applied Med. Res. Corp. v. U.S. Surgical Corp.*, 448 F.3d 1324, 1334 (Fed. Cir. 2006). For example, in *Medtronic v. Advanced Cardiovascular Systems*, the parties disputed the claim construction of a "means for connecting adjacent elements together"—an undisputed means-plus-function term. 248 F.3d 1303, 1310–11 (Fed. Cir. 2001). The center of the dispute was whether "the straight wire, hooks, or sutures [disclosed in the specification] [were] clearly linked or associated with the function of connecting adjacent elements together." *Id.* at 1311. This Court agreed that while "each of these structures is capable of performing the recited function," there was no "clear link or association" between the specification's description of "straight wire, wire hooks, and suture ties" to the "function of connecting adjacent elements together." *Id.* at 1311–13. So too here. The "position and orientation guide," "optional position and orientation guide automatic controller" and "local

measuring and imaging programming and processing unit" do not perform the claimed function.

The specification is equally unhelpful for Densys. A patent's written description can sometimes transform a means-plus-function element into a structural limitation if it clearly sets forth a "structural definition of a nonce term." *MTD Prods., Inc. v. Iancu*, 933 F.3d at 1342–45 (distinguishing "expressly defin[ing] the claim term" from providing corresponding structure). The '707 patent's specification, however, provides no such definition. It simply describes the measuring and imaging in the same functional terms as the claims. *See, e.g.*, Appx200–201(2:46–58, 3:44–61); Appx207(16:22–44). Were there any doubt, the specification teaches that the "measuring device" and "imaging device" are "general, and are applicable to *any category* … of automatic three-dimensional shape measurement, imaging, and mapping of objects and features." Appx200(2:46–50). That hardly limits the claim term to a specific structural definition.

This Court's reasoning in *Williamson* thus applies with equal force here. The relevant limitation in that *en banc* decision recited a "distributed learning control module for receiving communications transmitted between the presenter and the audience member computer systems and for relaying the communications" to the intended recipient. 792 F.3d at 1344. This Court recognized that the "distributed learning control" prefix modified "module," but held that prefix "does not provide

any structural significance" because nothing in the claims or the specification "inform[s] the structural character of" a distributed learning control module. *Id.* at 1351. The claims and the specification are just as silent here.

For that reason, the claimed measuring and imaging device is a means-plus-function term subject to the requirements of Section 112(f). At a minimum, this requires vacating the judgment and remanding for a new claim construction; however, as explained below, there is no corresponding structure, so this Court should hold the claims indefinite as a matter of law.

B. The Specification Does Not Disclose Corresponding Structure

Because the claimed measuring and imaging device is a means-plus-function term, the Court "must specifically review the specification for 'corresponding structure.'" *Apple*, 757 F.3d at 1296. "Structure disclosed in the specification qualifies as corresponding structure if the intrinsic evidence clearly links or associates that structure to the function recited in the claim." *Fintiv, Inc. v. Paypal Holdings, Inc.*, 134 F.4th 1377, 1384 (Fed. Cir. 2025). Not all patents contain the necessary link, and in those cases where "the specification fails to disclose adequate corresponding structure," any claim containing the means-plus-function term "is indefinite." *Traxcell Techs., LLC v. Sprint Commc'ns Co. LP*, 15 F.4th 1121, 1134 (Fed. Cir. 2021); *see also Nautilus, Inc. v. Biosig Instruments, Inc.*, 572 U.S. 898, 909–910 (2014).

That is the case here. Densys suggested in passing below that the passage at column 16, lines 22-32, provided the necessary structure. Appx917. In language virtually identical to dependent claims 18 and 54, that statement merely identifies fourteen purported "categor[ies] of mechanisms" the measuring and imaging device can employ. Appx207(16:22–32). Those are not structural limitations for the reasons discussed above, and even if they were, those broad categories would cover every possible way to take intra-oral measurements and images. Densys even listed mechanisms of action, like electro-mechanical mechanisms, that the '707 patent elsewhere disparages. *Compare* Appx207(16:22–32), *with* Appx202(6:52–7:7). Other statements in the specification disclose that "measuring" and "imaging device[s]" are "general" terms that "appl[y] to *any* category" of techniques for measuring and imaging objects and features. Appx200(2:46–50). Mapping a means-plus-function term "to every known way of achieving the claimed function" does not disclose "adequate structure" to avoid indefiniteness. *Synchronoss Techs., Inc. v. Dropbox, Inc.*, 987 F.3d 1358, 1367–68 (Fed. Cir. 2021).

During claim construction, Densys also looked to the sole figure in the '707 patent for corresponding structure. Appx575. The figure depicts "measuring and imaging device 36" as a black box with no structural detail, but a disclosure that "is essentially a black box that performs a recited function" is not a description of

structure. *Blackboard, Inc. v. Desire2Learn, Inc.*, 574 F.3d 1371, 1383 (Fed. Cir. 2009) (holding term indefinite).

The description of the figure underscores the lack of corresponding structure. It teaches that the measuring and imaging device in the figure includes "the variety of standard components and mechanisms for enabling measuring, imaging, and mapping, intra-oral objects and features." Appx207(15:9–16). A generic reference to standard components and mechanisms is not a sufficient disclosure of corresponding structure. *See Lufthansa Technik AG v. Astronics Advanced Elec. Sys. Corp.*, 711 Fed. App'x 638, 640 (Fed. Cir. 2017); *Ergo Licensing, LLC v. CareFusion 303, Inc.*, 673 F.3d 1361, 1365 (Fed. Cir. 2012). It does not meaningfully constrain the scope of the means-plus-function term or allow a skilled artisan to envision the combination of structural features that perform the claimed function.

The only specific components it identifies are the same "position and orientation guide," "position and orientation guide automatic controller," and "local measuring and imaging programming and processing unit" included in dependent claims 17 and 53. Appx207(15:9–16). The specification provides some structural description for the guide and its automatic controller, but none of those structures correspond to the relevant function: measuring and imaging the intra-oral objects and features. But the only structure that matters—the only structure that could be

corresponding structure for the claimed function—is structure that performs that function. Unrelated structure for performing different functions is irrelevant.

Thus, in the end, the '707 patent lacks any corresponding structure for the functionally claimed "measuring and imaging device." If the Court disagrees and finds some corresponding structure in the specification, it should vacate and remand for a new trial to decide whether the accused products contain those structures. *See Generation II Orthotics Inc. v. Med. Tech. Inc.*, 263 F.3d 1356, 1367–68 (Fed. Cir. 2001). But a remand is unnecessary here. The asserted claims are invalid, and the judgment should be reversed.

II. THE CLAIMS REQUIRE MEASURING THE DISTANCE BETWEEN THE DEVICE AND THE FIXED GLOBAL REGISTRATION POSITION

The district court separately misconstrued two related terms that each require measuring the distance between the measuring and imaging device and the fixed global registration position. The first term, which appears in claim 1, recites the step of "recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position." Appx211(24:53–55). The second term, in claim 37, is even more explicit that the claims require measuring distance. That term provides that the mobile registration device must "*measur[e]* and record[] global positions and orientations of said measuring and imaging device relative to same said intra-oral fixed global registration position." Appx214(29:56–59).

The district court nonetheless held the "plain and ordinary meaning" applied "for both terms *with no measurement of distance required*." Appx39. That construction cannot be reconciled with the language of the claims or the description of the invention in the specification. Measuring the distance between the device and the fixed global registration position is the only way the '707 patent lays out for recording the position of the device relative to the fixed position—and certainly the only way for *measuring* the device's position relative to the global fixed point. The Court should correct the district court's flawed construction and remand for a new trial.

The language of the claim is "the starting point of any claim construction analysis." *Hologic, Inc. v. Minerva Surgical, Inc.*, 44 F.4th 1358, 1367 (Fed. Cir. 2022). Here, claim 1 again requires "recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position." Appx211(24:53–55). By its terms, this necessarily entails measuring the distance between them. The global position of an object is not a qualitative term. It is a precise point, and the way to determine where that point falls relative to a fixed position is by calculating the distance separating the two positions. If 17 units in the x-direction, 10 units in the y-direction, and 3 units in the z-direction separate the measuring and imaging device from the global registration position, the system can record that the device's position is (17, 10, 3) relative to the fixed position.

Claim 37 is even clearer. The measurement requirement is right there in the language of the term, which requires "*measuring* and recording" the measuring and imaging device's relative position. Appx214(29:56–59). The way to measure the device's position relative to a fixed point is to take a measurement. Appx214(29:39–59). And Densys did not propose any relevant measurement other than the distance between the global fixed point and the measuring and imaging device. Appx214(29:39–59). Nor could it. The claims compare relative positions within images, not the relative circumference or mass of the objects or some other metric.

The surrounding claim language confirms that recording the position of the measuring and imaging device relative to the fixed global registration position requires measuring the distance between them. *See Intel Corp. v. Qualcomm Inc.*, 21 F.4th 784, 791–92 (Fed. Cir. 2021); *Hockerson-Halberstadt, Inc. v. Converse Inc.*, 183 F.3d 1369, 1374 (Fed. Cir. 1999). Claim 1 is directed to "[a] method for real-time intra-orally acquiring and registering three-dimensional *measurements* and images of intra-oral objects and features." Appx211(24:30–32). Consistent with that purpose, the reason the claimed method "record[s] said global position of said measuring and imaging device" is "for forming at least one globally recorded three-dimensional *measurement* and image of the intra-oral objects and features." Appx211(24:50–58). The method further requires repeating this process "for a

plurality of said global positions" to "form a plurality of said globally *recorded* three-dimensional *measurements*." Appx211(24:59–65).

Claim 37 includes the same requirements. It is directed to "a system for intra-orally acquiring and registering three-dimensional *measurements* and images of intra-oral objects and features." Appx214(29:39–41). The system fulfills that objective using essentially the same process as claim 1 and for essentially the same purpose. Appx214(29:39–59). But claim 37 adds that it not only records the relative global positions of the measuring and imaging device but also "*measur[es]*" those positions "relative to same said intra-oral fixed global registration position." Appx214(29:52–59). There is no escaping that this involves measuring the distance between those two points.

Dependent claims 6 and 42 reinforce this conclusion. Those dependent claims provide that the claimed intra-oral fixed global registration device is "for measuring and determining *distances* of said measuring and imaging device to said intra-oral fixed global registration position." Appx212(25:32–35); Appx214(30:17–20). This claim language makes even more explicit what was already evident from the language of the independent claims: the relative position of the device is determined by measuring distance. Indeed, Densys did not identify below any other type of measurement that could meet the independent claims' measurement requirement. *E.g.*, Appx1905–1906(340:1–11, 341:6–9); Appx1919(354:22–24);

Appx1935(370:4–9). Adopting this understanding of what the independent claims require does not pose a claim differentiation problem because claims 6 and 42 further add "an optional substrate for holding said intra-oral fixed global registration device." Appx212(25:36–37); Appx214(30:21–22). The independent and dependent claims thus have different scope under 3Shape's proposed construction. *See Tandon Corp. v. U.S. Int'l Trade Comm'n*, 831 F.2d 1017, 1023 (Fed. Cir. 1987); *Dow Chem. Co. v. United States*, 226 F.3d 1334, 1341–42 (Fed. Cir. 2000).

The specification, for its part, consistently identifies taking measurements relative to a global fixed position as one of the claimed invention's innovative features. For example, it states that "the present invention" "significant[ly] improve[s]" the prior art "by providing an effective and efficient method and system for acquiring and *registering three-dimensional measurements* and images of intra-oral objects . . . which are *all registered to the same intra-oral fixed global registration position*." Appx204(10:14–22). The claimed system and method achieve this asserted improvement by using a "mobile registration device, for enabling *measure[ments]* and recording global positions and orientations of the measuring and imaging device, 36, *relative to the intra-oral fixed global registration position*." Appx208(17:11–14). The specification elsewhere teaches the mobile registration device—the same device that performs the measuring and registering in claim 37—performs the "process of *measuring* and recording global positions . . . of

measuring and imaging device 36 in global coordinate space 30, *relative to intra-oral fixed global registration position*." Appx208(17:38–44).

These are not isolated examples. Every description in the specification of how to determine the "global position . . . relative to the intra-oral fixed global registration position" involves measuring. Appx204(9:28–30). The specification says "[t]here is [] a need for" a "method and system for real time intraorally acquiring and registering three-dimensional measurements." Appx203(8:61–64); *see also* Appx204(9:4–8). To fulfill that purported need, the patent describes "an intra-oral fixed global registration device 34, used for measuring and determining distances from intra-oral global registration position 28 to a measuring and imaging device." Appx205(12:58–61); *see also* Appx204(9:62–65). Other passages tout "acquiring three-dimensional measurements . . . and recording the various positions and orientations of the measuring imaging device relative to the same intra-oral fixed global registration position." Appx205(11:24–35); *see also* Appx204(10:14–22); Appx205(11:36–44). There is simply no basis for ignoring these clear statements about what the claimed invention requires. *See, e.g.*, *Microsoft Corp. v. Proxyconn, Inc.*, 789 F.3d 1292, 1299 (Fed. Cir. 2015); *VirnetX, Inc. v. Cisco Sys., Inc.*, 767 F.3d 1308, 1317 (Fed. Cir. 2014). "[W]here, as here, a patent repeatedly and consistently characterizes a claim term in a particular way, it is proper to construe the claim term in accordance with that characterization." *Wis. Alumni Rsch. Found. v. Apple Inc.*,

905 F.3d 1341, 1351 (Fed. Cir. 2018) (internal citations omitted); *Stylwan IP Holding, LLC v. Stress Eng'g Servs.*, 2025 WL 1501716, at *4 (Fed. Cir. May 27, 2025).

To the extent Densys asks the court for the first time on appeal to give claims 1 and 37 different constructions, the Court should reject that invitation. Although claim 37 expressly mentions measuring while claim 1 does not, this is not a meaningful difference given the surrounding language in both claims and the consistent descriptions in the specification. Indeed, both sides treated the relevant language in claims 1 and 37 as substantively identical below. Appx570–572; Appx636–637; Appx880–882; Appx922–923; Appx1048. "[T]he various claims all just seem to say the same thing differently phrased." *Traxcell Techs., LLC v. Nokia Sols. & Networks Oy*, 15 F.4th 1136, 1143 (Fed. Cir. 2021); *see also Sound View Innovations, LLC v. Hulu, LLC*, 166 F.4th 958, 966 (Fed. Cir. 2026). What both claims say, in slightly different words, is that the claimed method and system involves measuring the distance between the measuring and imaging device and the fixed global position. Appx570–572; Appx636–637; Appx858–860; Appx922–923; Appx1048. The district court's flawed construction thus requires a remand for a new trial. *See IQRIS Techs. LLC v. Point Blank Enters., Inc.*, 130 F.4th 998, 1005 (Fed. Cir. 2025); *Network-1 Techs., Inc. v. Hewlett-Packard Co.*, 981 F.3d 1015, 1021–22 (Fed. Cir. 2020).

III. 3SHAPE DOES NOT INFRINGE BECAUSE ITS DEVICES DO NOT USE A "FIXED GLOBAL REGISTRATION POSITION"

Rather than remand, however, the Court should simply reverse the jury's infringement verdict. As is evident from the previous claim term, claims 1 and 37 both require establishing "an intra-oral fixed global registration position inside the oral cavity." Appx211(24:35–36); Appx214(29:44–45). 3Shape's accused TRIOS scanners do not rely on a fixed global registration position, but instead stich multiple images together by using multiple local coordinate systems that change over time and identifying overlapping regions within subscans—the very approach the specification disparages and distinguishes. Appx2166–2167(601:25–602:5); Appx2351(786:7–25); Appx202–203(6:34–51, 7:8–36). No reasonable jury could conclude otherwise because Densys failed to identify evidence satisfying the district court's own construction. Thus, the accused scanners do not infringe claims 1 and 37 as a matter of law. *See ACCO Brands*, 501 F.3d at 1311–14.

A. The Claims Require Using An "Intra-oral Fixed Global Registration Position"

The district court construed "an intra-oral fixed global registration position inside the oral cavity" to mean "*a fixed position* inside the oral cavity that is used as *a reference point* for relating multiple sets of three-dimensional data to *a fixed global reference coordinate system*." Appx38. 3Shape does not dispute this claim

construction on appeal, which its technical expert applied in his non-infringement analysis. Appx2352–2353(787:24–788:6).

The '707 patent explains that "[g]lobal coordinate space 30 is associated with a fixed global reference coordinate system, such as fixed global reference orthogonal coordinate system 32, featuring fixed global coordinate system axes, X_G-axis, Y_G-axis, Z_G-axis, and fixed global coordinate system origin, O_G." Appx205(12:35–40); *see also* Appx208(17:15–23). The '707 patent further confirms that the "intra-oral fixed global registration position 28 is *defined by a particular fixed location* within global coordinate space 30 of oral cavity 26." Appx209(19:42–45); *see also* Appx211(23:55–58) ("the intra-oral fixed global registration position, 28, is *defined by a particular fixed location* within global coordinate space of the oral cavity of [t]he dental patient"). Indeed, the specification states that "[a]n important consequence of this aspect of the present invention, is that of enabling real time, continuously or discontinuously, acquiring and registering three-dimensional measurements and images of intra-oral objects and features located in multiple fields of view . . . which are all registered to *the same intra-oral fixed global registration position*." Appx211(23:62–24:4); *see also* Appx210(22:42–45) ("forming a plurality of sets of global coordinate space pixel positions in global coordinate space which are registered relative to *the same intra-oral fixed global registration point*."); Appx210(22:60–67) ("forming a plurality of sets of global coordinate space pixel

positions . . . which are registered relative to *same intra-oral fixed global registration point* 28 in oral cavity 26 of the dental patient."). In fact, the '707 patent reiterates in *twenty-four places* that the "intra-oral fixed global registration position" is the same position throughout the process of acquiring and registering three-dimensional measurements. And there is nothing in the '707 patent specification that suggests "an intra-oral fixed global registration position inside the oral cavity" is not fixed and may be redefined throughout the process of "acquiring and registering three-dimensional measurements." *See, e.g.*, Appx211–212(24:30–25:7).

Thus, the patent confirms this "fixed location" is indeed fixed and does not change positions during the process of acquiring and registering three-dimensional measurements. *See, e.g.*, Appx211–212(24:30–25:7). As a matter of logic, any contrary conclusion would read the word "fixed" out of the claim. *See Texas Instruments Inc. v. U.S. Int'l Trade Comm'n*, 988 F.2d 1165, 1171 (Fed. Cir. 1993) (concluding that claims should not be construed in a manner that renders other terms in the claim as "mere surplusage").

B. 3Shape's TRIOS Scanners Do Not Use A Single "Intra-oral Fixed Global Registration Position"

3Shape's TRIOS Scanners (i.e., the accused products) do not use an "intra-oral fixed global registration position," and as such, there is no substantial evidence to support the jury's verdict of infringement. This Court should reverse the jury's finding of infringement.

As 3Shape explained at trial, the TRIOS system uses a fundamentally different process than the '707 patent to "acquiring and registering three-dimensional measurements." *See, e.g.*, Appx211–212(24:30–25:7). 3Shape's expert, Dr. Egbert, explained there are multiple techniques for image registration. Appx2336(771:18–21). One method involves "overlapping scans" whereby the overlap between different images allows each image to be moved from its local space into its correct global space position. Appx2339(774:7–18). Then an algorithm identifies the points that are closest together and determines the "closest fit between all of the points," of the "overlapping images." Appx2340–2341(775:8–776:1). The result of this algorithm is a three-dimensional scan with "the best overlap [the algorithm] can find." Appx2340–2341(775:22–776:1). A second method uses a "tracking based registration" whereby a fixed position in the oral cavity is established, and then each measurement and image taken by the device is recorded relative to the fixed position. Appx2341(776:6–14). In this method, the position of the camera is known relative to that same fixed position in the oral cavity such that it is always known where the camera is located when an image is taken. Appx2341(776:15–24).

The TRIOS scanners use the first method. *See* Appx2362(797:10–15) (Dr. Egbert confirming that 3Shape uses the "overlapping scan" process for scanning to obtain a full 3D model of a scanned area); *see also* Appx2352(787:11–15)

(explaining 3Shape's technology works fundamentally differently from the processes described in the '707 patent). The '707 patent relates to the later method. *See supra* § III.A; Appx38 (construing "an intra-oral fixed global registration position inside the oral cavity" as "*a fixed position* inside the oral cavity that is used as *a reference point* for relating multiple sets of three-dimensional data to *a fixed global reference coordinate system*"). Indeed, the '707 specification differentiates the "overlapping images" techniques known in the prior art from the "tracking based registration" with a fixed global registration position by explaining that the former requires "skillfully, and timely, during a patient visit, . . . re-position[ing] [the measuring and imaging device] in the same field of view of each other particular set of intra-oral objects and features being measured and imaged by an operator." Appx203(7:8–19). This is consistent with Dr. Egbert's testimony that when the TRIOS system scans an image, that image must overlap with a previous image in order for it to be useful. Appx2351–2352(786:22–787:6).

That backdrop sets the stage for why the TRIOS scanners operate fundamentally differently from what is required by the claims—the TRIOS scanners do not use an "intra-oral fixed global registration position" because it does not use a position that is fixed and used to relate successive scans to each other. At trial, Densys identified the "center of mass" as the "fixed position inside the mouth." Appx1882(317:9–12); *see also* Appx1938–1939(373:11–374:8). During trial,

3Shape explained what the "center of mass" is and how it "is used in the 3Shape system to set up the . . . global coordinate system." Appx2355(790:7–18]. Critically, however, "[o]nce you've set up that global coordinate system, *that center of mass is gone*. You don't have it anymore. It's not stored in the system, it's not there. And you don't have it -- you don't have access to it anymore." Appx2355(790:21–24) (emphasis added). "[The] center of mass is computed once. It's . . . just an average of a bunch of points. It's not a fixed position inside the oral cavity. And once you've computed it and moved that first scan to the world coordinate space, *then it's gone*. You don't use it anymore. It's not used for relating multiple sets of data to anything because it's completely gone. You don't have it; it's not stored anywhere." Appx2356(791:6–13) (emphasis added); *see also* Appx2357–2360(792:9–795:18); Appx2399(834:3–25); *see also* Appx2260(695:4–7) (confirming the TRIOS scanners would still function if someone deleted the center of mass after the first subscan).

This irrelevance of the center of mass after the first scan confirms that the center of mass cannot be the claimed "intra-oral fixed global registration position" construed as "a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system." Appx38. As explained above, the specification requires registering all three-dimensional measurements and images of the intra-oral objects

"to *the same* intra-oral fixed global registration position." Appx211(23:62–24:4) (emphasis added); Appx210(22:42–45); Appx210(22:60–67). That is not possible if the alleged "intra-oral fixed global registration position" is deleted after the first subscan as is the case in the TRIOS systems.

At bottom, the alleged "fixed global registration position" Densys identified is not fixed and is not used to establish the location of intra-oral objects within a global coordinate system. 3Shape's products instead indisputably use overlapping scans to establish where those intra-oral objects sit within the global coordinate system—the same technique that the '707 patent disparages and distinguishes. Given these facts, no reasonable jury could have found that 3Shape infringes.

IV. THE JURY'S WILLFULNESS VERDICT SHOULD BE REVERSED

Finally, the Court should reverse the jury's willfulness verdict. No reasonable jury could find that 3Shape "had a specific intent to infringe at the time of the challenged conduct." *Provisur Techs., Inc. v. Weber, Inc.*, 119 F.4th 948, 955 (Fed. Cir. 2024). Densys's willfulness case rested largely on videos 3Shape shared with dentists demonstrating one way to use 3Shape's intra-oral scanners and on a notice letter Densys sent in 2012, well before accused products were on the market. Appx[Tr. 785:5–17]. Neither demonstrates "deliberate or intentional infringement." *Bayer Healthcare LLC v. Baxalta Inc.*, 989 F.3d 964, 988 (Fed. Cir. 2021).

The videos show a dentist using one of 3Shape's intra-oral scanners and demonstrates one way to take a full scan of a patient's mouth. Appx3531; Appx3576. It is undisputed that 3Shape wanted dentists to follow the instructions in the video, but that only proves so much. The video never discusses patents, never makes reference to patents, and never indicated 3Shape knew the steps outlined in the video would infringe claims 1 or 37. Appx3531; Appx3576. But 3Shape's knowledge that the steps in the video would infringe is a necessary threshold showing for a willfulness claim. *See Bayer Healthcare*, 989 F.3d at 988 ("Knowledge of the asserted patent and evidence of infringement is necessary, but not sufficient, for a finding of willfulness. Rather, willfulness requires deliberate or intentional infringement.").

To fill that gap, Densys turned to the 2012 letter. It too is not enough. The letter at most put 3Shape on notice that the '707 patent exists and that Densys asserted (without explaining why) that 3Shape's original scanner infringes—a scanner Densys never accused of infringement in this case. The letter in its entirety reads:

> Please take notice that in regard to the intra-oral scanner, 3Shape is infringing on the following patents of densys3D: US Patent – 6402707; Patent Applications – EP1296592, JP4502137, and IS153599.

Appx3532. The letter does not mention any of the accused products because those products were not on the market in 2012. Appx1866(301:1–6); Appx3532. The

only product 3Shape had on the market at the time was the TRIOS Standard Cart. Appx1866(301:1–6); Appx3532; Appx3533–3575; *see also* Appx1416–1417.

Even for the TRIOS Standard Cart (the only possible product the letter could refer to), the letter did not provide claim charts or any other information explaining how 3Shape allegedly infringed the '707 patent "in regard to the intra-oral scanner." Appx3532. The letter thus does not count for much because knowledge of the patent standing alone is "not sufficient[] for a finding of willfulness." *Bayer Healthcare*, 989 F.3d at 988. Densys must show that 3Shape knew its products infringe. *Id.* But its threadbare accusation cannot establish that 3Shape had the requisite knowledge, especially when the relevant products had not yet launched and were not the subject of the letter.

Densys thus resorted to attacking the investigation that 3Shape voluntarily undertook in 2012 after receiving the letter—*an investigation 3Shape conducted seven years before Densys filed suit*. Appx2174–2175(609:22–610:4). Upon receiving the letter, 3Shape's Project Manager at the time, Dr. Karl Hollenbeck, and a 3Shape patent agent, Mr. Mikkel Ninn-Grønne, reviewed the asserted patent. Appx2169–2171(604:12–606:16). Dr. Hollenbeck's analysis led him to conclude that 3Shape did not infringe the '707 patent because 3Shape does not use "a fixed global reference position":

> **Trios in view of claim 1 and 37**
>
> Trios does not use a global reference position to align the acquired images. Trios aligns images by using reference points on neighbouring images. Thus, non-neighbouring images are aligned using different reference points. Accordingly, a global reference position is not used since each image is aligned using different 'local reference points.
>
> The same basic arguments are valid for claim 37 as this also relates to a global reference position.

Appx3516; *see also* Appx2171(606:13–20]; Appx2173–2174(608:25–609:24). The accused products use the same basic alignment technique based on overlapping subscans or images, which does not infringe for the reasons discussed above. Appx1866(301:11–18); *see* Section III, *supra*. This is compelling evidence that 3Shape believed it had a reasonable non-infringement defense before the accused products even launched.

Densys leveled three criticisms of the investigation, all of which it claimed prove 3Shape had no good-faith non-infringement defenses. *First*, Densys told the jury that 3Shape should have "gotten an opinion" from a "U.S. lawyer":

> And what they should have done is they should have talked to a U.S. lawyer and gotten an opinion, a real opinion that considered U.S. law, considered how to interpret this patent and considered whether their product infringed. But they didn't. They pushed it along.

Appx2597–2598(1032:25–1033:4). This was apparently an effort to discredit 3Shape's reliance during its investigation on Mr. Ninn-Grønne, a European patent agent with experience evaluating U.S. patents. Appx2169–2171(604:12–606:20). Regardless, 3Shape's decision not to involve a U.S. lawyer is not evidence that it

acted willfully as a matter of law because "[t]he failure of an infringer to obtain the advice of counsel with respect to any allegedly infringed patent … may not be used to prove that the accused infringer willfully infringed the patent." 35 U.S.C. § 298. For that reason, "[p]atentees are prohibited from using the accused infringer's failure to obtain the advice of counsel as an element of proof that the accused infringer willfully infringed." *Provisur Techs.*, 119 F.4th at 955.

Second, Densys criticized 3Shape for not reviewing the TRIOS source code as part of its investigation. Appx2190–2192(625:11–627:7). This is a non sequitur. Dr. Karl Hollenbeck and Mr. Mikkel Ninn-Grønne both reviewed the '707 patent and determined 3Shape's technology does not infringe because it relies on using different reference points in neighboring images to align the images into a single scan. Appx2169–2171(604:19–606:20); Appx2173–2174(608:2–609:21); Appx3516–3520. Densys does not contend Dr. Hollenbeck and Mr. Ninn-Grønne misunderstood how the products worked and could have dispelled that misunderstanding by examining the code. Appx2184–2185(619:24–620:19); Appx2188–2192 (623:7–627:7). The parties simply have a genuine dispute about whether using different reference points in neighboring images still somehow relies on a single fixed global reference position. *See Focus Prods. Grp. Int'l, LLC v. Kartri Sales Co., Inc.*, 156 F.4th 1259, 1287–88 (Fed. Cir. 2025) (vacating the district court's finding of willful infringement where defendant made "reasonable,

good-faith efforts" to review the patents asserted against it and "came away with the understanding that [it was] complying with the law" (modification in original)).

Third, Densys mischaracterized Dr. Hollenback's testimony. It is true that his testimony, as the person who conducted 3Shape's internal investigation and response to the letter, confirmed that he viewed the allegations in the letter as a "minor issue":

> Q. Okay. Now, the reason that you were the person whose opinion that was solicited with regards to the Densys patent matter was because you were the project manager for TRIOS at the time, correct?
>
> A. Yes.
>
> Q. And you viewed this as a relatively minor issue that did not take much of your time, correct?
>
> A. Correct.

Appx2189(624:10–17). But that is because, as explained above, 3Shape and Dr. Hollenback reasonably believed the TRIOS Standard Cart did not infringe—a view that was apparently vindicated by Densys's decision not to accuse that product of infringement in this case—and Densys provided no details to substantiate its accusations. Appx2169–2171(604:19–606:20); Appx2173–2174(608:2–609:21); Appx3516–3520. Densys nonetheless twisted this testimony to suggest 3Shape viewed any infringement of the '707 patent as a minor issue it did not need to take seriously, asserting that Dr. Hollenbeck "viewed it as a minor issue and didn't take much time." Appx2598(1033:14–15). No reasonable jury could accept that

caricature of 3Shape's position, which involved a reasonable investigation into Densys's conclusory infringement accusation and which reached a reasonable conclusion about why 3Shape did not infringe.

Without any substantial evidence to support it, the jury's willfulness verdict and the subsequent enhanced damages award must be reversed.

CONCLUSION

The Court should reverse the district court's judgment or at a minimum remand for a new trial.

August 1, 2026

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CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATION

This brief complies with the type-volume limitation of Federal Rule of Appellate Procedure 32(a)(7). According to the word processing system used to prepare this brief, it contains 13,651 words.

August 1, 2026 */s/ John C. O'Quinn*

CERTIFICATE OF COMPLIANCE WITH FED. CIR. R. 25.1

This brief complies with Fed. Cir. Rule 25.1. Zero (0) unique words, as defined in the Court's Rule 25.1, are marked confidential in this brief. The only confidential information in this brief appears in the Addendum to the brief. That information is subject to the protective order entered by the U.S. District Court for the Western District of Texas on June 27, 2020.

/s/ John C. O'Quinn

CERTIFICATE OF SERVICE

On August 1, 2026, the non-confidential version of this brief was submitted to the Court by CM/ECF and thereby served on all parties, and the confidential version was served on the following counsel for Appellee via email.

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ADDENDUM

Claim Construction Order,
(Dkt. 160 Apr. 5, 2022).....Appx38–40

Verdict Form,
(Dkt. 186 Apr. 8, 2022).....Appx65–71

Order and Memorandum Denying Defendants' Renewed
Motion for Judgment as a Matter of Law,
(Dkt. 250 Oct. 30, 2025).....Appx138–167

Final Judgment,
(Dkt. 266 Feb. 20, 2026).....Appx195–197

United States Patent No. 6,402,707
(Jun. 11, 2025).....Appx198–216

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

DENSYS LTD,
Plaintiff

-VS-

3SHAPE TRIOS A/S, 3SHAPE A/S,
Defendants

§§§§§§§§§§§§§§§

W-19-CV-00680-ADA

CLAIM CONSTRUCTION ORDER

The Court held a *Markman* hearing on August 31, 2020. During that hearing, the Court provided its final constructions. The Court also held a subsequent *Markman* hearing on March 31, 2022. The Court now enters those claim constructions.

Claim Term	**Plaintiff's Construction**	**Defendants' Construction**	**Court's Construction**
"an intra-oral fixed global registration position inside the oral cavity." '707 Patent claims 1, 22, 37, 67, 68	"a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system"	"a fixed position defined inside the oral cavity prior to measuring and imaging and that is used as a reference point for relating multiple three-dimensional data sets"	"a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system"
"a fixed global reference coordinate system" '707 Patent claims 1, 37	Plain and ordinary meaning	"a global coordinate system defined by the intra-oral fixed global registration position"	Plain and ordinary meaning, where the plain and ordinary meaning is "a reference system used to define the locations of objects in the inter-oral cavity and whose origin point is fixed at a single location within the inter-oral cavity."

Claim Term	Plaintiff's Construction	Defendants' Construction	Court's Construction
"a measuring and imaging device (for measuring and imaging the intra-oral objects and features)" '707 Patent claims 1, 16-19, 21-24, 32, 37, 52, 55, 57, 59 and 60	Plain and ordinary meaning	Term is subject to 35 U.S.C. § 112, ¶ 6. and is indefinite	Not subject to § 112, ¶ 6. Plain and ordinary meaning
"recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position" (Claim 1) "measuring and recording global positions and orientations of said measuring and imaging device relative to same said intra-oral fixed global registration position" (Claim 37) '707 Patent claims 1, 37	Plain and ordinary meaning for both terms.	"recording the global position of the measuring and imaging device measured from the intra-oral fixed global registration position" (Claim 1) "measuring and recording global positions and orientations of the measuring and imaging device measured from the intra-oral fixed global registration position." (Claim 37)	Plain and ordinary meaning for both terms with no measurement of distance required.
"(f) registering local coordinate space pixel positions in each of said plurality of globally recorded three-dimensional measurements and images with corresponding global coordinate space pixel position" '707 Patent claims 1	Plain and ordinary meaning	(f) after step (e), registering local coordinate space pixel positions in each of said plurality if globally recorded three-dimensional measurements and images with corresponding global coordinate space pixel position.	Plain and ordinary meaning without an ordering of steps
"mobile registration device (for measuring and recording global positions and orientations of said measuring and imaging device)" '707 Patent claims 37, 63-66, 68	Plain and ordinary meaning	Term is subject to 35 U.S.C. § 112, ¶ 6.	Not subject to § 112, ¶ 6. Plain and ordinary meaning

Claim Term	**Plaintiff's Construction**	**Defendants' Construction**	**Court's Construction**
1. A method for real time intraorally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising the steps of: 37. A system for real time intraorally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, where the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising:	"real time" in the preamble is limiting	The preamble is not limiting.	"real time" in the preamble is limiting

SIGNED this 4th day of April, 2022.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

FILED
April 08, 2022
CLERK, U.S. DISTRICT COURT
WESTERN DISTRICT OF TEXAS
BY: Jennifer Clark
DEPUTY

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

DENSYS LTD.,

Plaintiff,

v.

3SHAPE TRIOS A/S and 3SHAPE A/S,

Defendants.

Civil Action No. 6:19-cv-00680-ADA

4/08/22
12:39 p

VERDICT FORM

In answering the following questions, you are to follow the instructions I have given you in the Court's jury charge. Your answers to each question must be unanimous. Some of the questions contain legal terms that are defined and explained in detail in the Final Jury Instructions. You should refer to and consider the Final Jury Instructions as you answer these questions in the Verdict Form.

As used herein:

- "Densys" refers to Plaintiff, Densys Ltd.
- "3Shape" refers to Defendants 3Shape TRIOS A/S and 3Shape A/S, collectively.
- "The '707 patent" refers to U.S. Patent No. 6,402,707.
- "Asserted Claims" refers to claims 1 and 37 of the '707 patent, collectively.

You must first answer Questions 1 through 2 before proceeding to any other parts of this Verdict Form. Please do not answer Questions 3 and 4 unless the instructions for those questions have been met.

QUESTION 1: LITERAL INFRINGEMENT

Did Densys prove, by a preponderance of the evidence, that 3Shape literally infringed any of the following Asserted Claims of the '707 patent?

Please check "Yes" or "No" for each listed Asserted Claim in the space provided. "Yes" is a finding for Densys. "No" is a finding for 3Shape.

Claim 1

Claim 1: Yes ✓ No _____

Claim 37

Claim 37: Yes ✓ No _____

Please proceed to the next question.

QUESTION 2: INDUCED INFRINGEMENT

Did Densys prove, by a preponderance of the evidence, that 3Shape induced others to infringe any of the following Asserted Claims of the '707 patent?

Please check "Yes" or "No" for each listed Asserted Claim in the space provided. "Yes" is a finding for Densys. "No" is a finding for 3Shape.

Claim 1

Claim 1: Yes ✓ No _____

Claim 37

Claim 37: Yes ✓ No _____

Please proceed to the next question.

IF YOU HAVE REACHED THIS POINT IN THE VERDICT FORM, YOU SHOULD HAVE ANSWERED QUESTIONS 1 THROUGH 2. IF YOU HAVE NOT ANSWERED QUESTIONS 1 THROUGH 2, PLEASE GO BACK AND ANSWER THEM BEFORE PROCEEDING.

If the answer to EVERY Asserted Claim listed in Questions 1 through 2 is "No," then do not answer questions 3 and 4 and proceed to the last page.

If the answer is "Yes" as to ANY claim in Questions 1 through 2 (*i.e.*, you found any claim infringed), please proceed to the next question.

QUESTION 3: DAMAGES

What is the amount of damages that you find Densys has proven, by a preponderance of the evidence, that compensate it for 3Shape's infringement of the claims of the '707 patent that you have found are infringed?

Please provide a dollar amount in the space provided.

$ 11.875 million

Please proceed to the question.

QUESTION 4: WILLFULNESS

If you entered a damage amount in Question 3, you may consider whether 3Shape's infringement was willful by answering the following question.

Did Densys prove, by a preponderance of the evidence, that 3Shape's infringement of the Asserted Claims was willful?

Please check "Yes" or "No" in the space provided. "Yes" is a finding for Densys. "No" is a finding for 3Shape.

Yes ✓ No _____

Please proceed to the next page.

You have now reached the end of the Verdict Form and should review it to ensure it accurately reflects your unanimous determinations. The jury foreperson should then sign and date this Verdict Form in the spaces below. Once this is done, please notify the Court Security Officer that you have reached a verdict. The jury foreperson should keep the Verdict Form and bring it when the jury is brought back to the court room.

I certify that the jury unanimously concurs in every element of the above verdict.

Jury Foreperson: [redacted]

Signed this 8th day of April, 2022.

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

DENSYS LTD., *Plaintiff,*	§	
-v-	§	**6:19-CV-00680-ADA**
3SHAPE A/S, 3SHAPE TRIOS A/S *Defendants.*	§	

[redacted] ORDER AND MEMORANDUM IN SUPPORT THEREOF DENYING DEFENDANTS' RENEWED MOTION FOR JUDGMENT AS A MATTER OF LAW

Before the Court is Defendants 3Shape A/S and 3Shape Trio A/S's Renewed Motion for Judgment as a Matter of Law (ECF No. 193), Plaintiff Densys Ltd.'s Opposition (ECF No. 220), and Defendants' Reply (ECF No. 223). The Court held a hearing on this motion and other post-trial motions on July 7, 2022. ECF No. 229.

I. BACKGROUND

Plaintiff filed this case on November 26, 2019 alleging infringement of, *inter alia*, U.S. Patent No. 6,402,707 (hereinafter "Asserted Patent"). The jury returned a verdict that Claims 1 and 37 were literally infringed, Defendants induced others to infringe Claims 1 and 37, awarded damages of $11.875 million, and Defendants willfully infringed the Asserted Claims. ECF No. 186 at 2, 3, 5, 6. Defendants filed this Renewed Motion for Judgment as a Matter of Law.

II. LEGAL STANDARD

"Judgment as a matter of law is proper when 'a reasonable jury would not have a legally sufficient evidentiary basis to find for the party on that issue.'" *Abraham v. Alpha Chi Omega*,

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708 F.3d 614, 620 (5th Cir. 2013) (quoting Fed. R. Civ. P. 50(a)). The non-moving party must identify "substantial" evidence to support its positions. *TGIP, Inc. v. AT&T Corp.*, 527 F. Supp. 2d 561, 569 (E.D. Tex. 2007). "Substantial evidence is more than a mere scintilla. It means such relevant evidence as a reasonable mind might accept as adequate to support a conclusion." *Eli Lilly & Co. v. Aradigm Corp.*, 376 F.3d 1352, 1363 (Fed. Cir. 2004). "The Fifth Circuit views all evidence in a light most favorable to the verdict and will reverse a jury's verdict only if the evidence points so overwhelmingly in favor of one party that reasonable jurors could not arrive at any contrary conclusion." *Core Wireless Licensing S.A.R.L. v. LG Elecs., Inc.*, 880 F.3d 1356, 1361 (Fed. Cir. 2018) (citing *Bagby Elevator Co. v. Schindler Elevator Corp.*, 609 F.3d 768, 773 (5th Cir. 2010)). A court must "resolve all conflicting evidence in favor of [the verdict] and refrain from weighing the evidence or making credibility determinations." *Gomez v. St. Jude Med. Daig Div. Inc.*, 442 F.3d 919, 937–38 (5th Cir. 2006).

Courts grant JMOL for the party bearing the burden of proof only in extreme cases, when the party bearing the burden of proof has established its case by evidence that the jury would not be at liberty to disbelieve, and the only reasonable conclusion is in its favor. *Mentor H/S, Inc. v. Medical Device Alliance, Inc.*, 244 F.3d 1365, 1375 (Fed. Cir. 2001). By contrast, JMOL is inappropriate if the record evidence is such that reasonable and fair-minded men in the exercise of impartial judgment might reach different conclusions. *Laxton v. Gap Inc.*, 333 F.3d 572, 579 (5th Cir. 2003).

III. LEGAL ANALYSIS

A. Whether there is substantial evidence of direct infringement

Defendants argue that there is no evidence they directly infringe the Asserted Claims. Mot. at 2. More specifically, Defendants state that Plaintiff's infringement theory alleges that the center of mass of the first subscan (3D image) meets the "intra-oral fixed global registration position" limitation. Mot. at 2 (citing Tr. at 317:6–13, 322:23–323:4, 350:19–351:1, 366:10–16, 373:25–374:25, 661:5–22, 691:11–693:14, 735:17–21, 789:25–790:24, 844:13–845:10). But Defendants assert that the Accused Products do not have a center of mass of the first subscan (3D image) when they are sold, but rather only acquire that subscan when the Accused Products are used to scan a dental patient's mouth in United States. *Id.* Defendants contend that "[p]roof of sales in the United States is insufficient to establish direct infringement because the product itself does not include the center of mass." *Id.* at 2. Defendants contends that "to prove that [Defendants] directly infringed, [Plaintiff] had to establish that [Defendants] actually *used* the [Accused Products] and performed an intra-oral scan of a dental patient in the United States." *Id.* at 2–3 (emphasis in Defendants' brief). Defendants argue that no such evidence exists as they are a Danish company that sells the Accused Products through third-party distributors. *Id.* at 3 (citing Tr. at 505:15–506:14).

In its opposition, Plaintiff argues that sales of the Accused Products are substantial evidence of direct infringement and use was proven. Opp. at 2–5. Plaintiff asserted method Claim 1 and system Claim 37. With respect to the system claims, Plaintiff contends that "[i]t is well-established that sales of products that practice a claim's elements are sufficient for liability with respect to apparatus or system claims." *Id.* (*Silicon Graphics, Inc. v. ATI Techs., Inc.*, 607 F.3d 784, 794 (Fed. Cir. 2010)). In particular, Plaintiff claims that the Accused Products "are sold pre-

programmed with software that will necessarily create[] a fixed global registration position when used for its intended purpose" and "always use[] that fixed point in the mouth in an established way defined in [Defendants'] software." *Id.* at 2–3. Plaintiff states that they presented source code evidence that the Accused Products operated in this manner. *Id.* at 3 (citing Tr. at 363:25–366:2). Plaintiff also states that Defendants do not allege that the accused software operates in a different way or that it can operate without "first acquiring the data representing a center of mass." *Id.*

Plaintiff asserts that the claims do not require that the user perform any actions. *Id.* Rather, Plaintiff contends that the Accused Products were "capable of infringement 'in the manner prescribed by Defendants, in accordance with the design of the product.'" *Id.* at 3–4 (citing *SiRF Tech., Inc. v. ITC*, 601 F.3d 1319, 1329 (Fed. Cir. 2010); Tr. at 240:3–7, 730:3–731:1, 731:16–21, 732:4–13; *Mass Engineered Design, Inc. v. Ergotron, Inc.*, 633 F.Supp. 2d 361, 376-78 (E.D. Tex., Apr. 17, 2009)).

With respect to use, Plaintiff argue that there is trial testimony that Defendants conducted "customized trainings" and "presentations" in the United States for domestic customers and resellers, Defendants' customers asked for "*more* face-to-face training in using the system for dentist(s) and staff[,]" and "the many trade shows where [Defendants] openly demonstrated new versions of the accused products." *Id.* at 5 (citing Opp., Ex. 3 at 5; Tr. at 548:8–18; Opp., Ex. 4 at 3Shape_ITC_00087118, 125, 144, 145, 163, 164; Opp., Ex. 5 at 35, 46–47, 82, 93). Plaintiff also argues that Defendants abandoned their argument that there was no use within the United States by dentists after reviewing the transcript, perhaps because Defendants sell annual subscriptions whose prices depends on the number of uses and because Plaintiff presented evidence of uses by U.S. dentists. *Id.* (Opp., Ex. 4; Ex. 3 at 1–3; Ex. 5 at 2, 17, 22–23, 28).

Plaintiff argues that Defendants' new arguments are waived because Defendants never clearly argued that there is no evidence Defendants themselves used the accused device in their Rule 50 motion. *Id.* at 6. Had Defendants raised those issues, Plaintiff could have relied on additional evidence of Defendants' scanner use in the United States. *Id.*

In their reply, with respect to the system claims, Defendants contend that the Accused Products are "neither 'intra-oral' nor 'inside the oral cavity of the dental patient' and as such cannot meet this limitation." Reply at 1. More specifically, Defendants contend that the Accused Products can capture scans outside the patients' mouth (*i.e.*, not intra-oral), so it is up to the dentist where make the first subscan. *Id.* at 1–2.

Defendants argue that their "intended use of [the Accused Products] cannot legally support a finding of direct infringement based solely on the sale of the scanner." *Id.* at 2. Defendants further argue that *SiRF Tech* is inapposite because in that case the claims did not require the end user to perform part of the claims, whereas in this case, "infringement depends on whether the end user uses [the Accused Products] to scan in a patient's mouth." *Id.* (citing *SiRF Tech.*, 601 F.3d at 1329; Tr. at 685:16–23, 837:11–13.).

With respect to use, Defendants first argue that Plaintiff only presented documentary evidence of use, but these documents do not establish use by Defendants (only that of use by an end user). *Id.* at 3. Defendants next argue that "the fact that third-parties can use [the Accused Products] to perform intra-oral scans on dental patients in the United States does not show *direct* infringement by [Defendants]." *Id.* (emphasis in Defendants' brief).

The Court's Analysis:

The Court agrees that there is substantial evidence of direct infringement to support the jury's decision. Because Claim 37, for example, is a system claim as opposed to a method claim, the sale of the Accused Products is an infringing act. *Silicon Graphics*, 607 F.3d at 794. Furthermore, there does not appear to be any dispute that the software in the Accused Products are sold pre-programmed that will create a fixed global registration position when used for its intended purpose. In addition, the apparatus claims do not require that the user perform any actions. *See, e.g.*, '705 Patent, Claim 37.

Defendants attempt to raise an argument that the end user may decide to run a scan outside the patient's mouth to meet the "intra-oral fixed global registration position" limitation. As a preliminary matter, the Court believes that Defendants waived that argument, as demonstrated by failing to address it in their reply. Reply at 1–3.

In any event, the Court agrees with Plaintiff that the Accused Products are an intraoral scanner and thus would only be used inside the mouth. *SiRF Tech.*, 601 F.3d at 1329. Furthermore, Defendants' argument assumes that while nothing stops the dentist from running the scan outside the mouth, doing so would undermine the purpose of an "intraoral scanner," in addition to compromising the accuracy of such a scanner. Furthermore, there is no evidence to support that an end user ever undertook such an unusual and counterproductive step, which indicates that Defendants' argument is only a theoretical possibility that was never realized. In addition, even if there was an unusual extraoral use of the intraoral scanner, *e.g.*, by accident, which would not infringe, that does not mean that the intraoral scanner did not subsequently take a scan inside the patient's mouth, which would still meet the claim limitation. By contrast, the only evidence in the record appears to be from Plaintiff demonstrates that the scanner was only used intraorally. *See,*

e.g., Opp., Ex. 3 at 5; Tr. at 548:8–18; Opp., Ex. 4 at 3Shape_ITC_00087118, 125, 144, 145, 163, 164; Opp., Ex. 5 at 35, 46–47, 82, 93; Opp., Ex. 4; Ex. 3 at 1–3; Ex. 5 at 2, 17, 22–23, 28).

With respect to the use of the method claims, the Court concludes that Plaintiff has provided substantial evidence of use. *See, e.g.*, Opp., Ex. 3 at 5; Tr. at 548:8–18; Opp., Ex. 4 at 3Shape_ITC_00087118, 125, 144, 145, 163, 164; Opp., Ex. 5 at 35, 46–47, 82, 93; Opp., Ex. 4; Ex. 3 at 1–3; Ex. 5 at 2, 17, 22–23, 28).

In any case, the Court believes that Defendants also waived their argument that an end user—and not Defendants—used the Accused Products to scan a patient's mouth in the United States, as demonstrated by failing to address it in their reply. Reply at 1–3.

B. Whether there is substantial evidence of induced and willful infringement

Recovery is barred "for any infringement committed more than six years prior to the filing of the complaint[.]" *Roche Diagnostics Corp. v. Meso Scale Diagnostics, LLC*, 30 F.4th 1109, 1119 (Fed. Cir. 2022) (quoting 35 U.S.C. § 286).

Defendants argue that, in order to prove induced or willful infringement, Plaintiff needs to show that Defendants "committed an inducing and/or willful act of infringement during the damages period of 35 U.S.C. § 286, that is after November of 2013" and their knowledge of infringement also originated after that date. Mot. at 3. With respect to the latter, Defendants contend that the only evidence of intent is a 2012 letter from Plaintiff (alleging infringement of Defendants' product released in 2011), which is before the six year damages period. *Id.* at 3, 5.

With respect to acts of induced infringement, Defendants allege that because Plaintiff's letter did not explain why the 2011 scanner infringed the Asserted Patent and Plaintiff never reached out again until the filing of this lawsuit, Defendants were not put on notice that subsequent products (released in 2013, 2015, 2017, and 2019) would infringe. *Id.* at 4–5.

With respect to acts of willful infringement, Defendants argue that they cannot be held liable for willful infringement, as long as that belief is reasonable. *Id.* (citing *Commil US v. Cisco Sys., Inc., v. CITE*, 575 U.S. 631, 641 (2015)). Defendants argue that they subjectively believed that they did not infringe after they conducted an investigation in response to the 2012 letter and determined that they Accused Products did not include an "intra-oral fixed global registration position." *Id.* Defendant argues that Plaintiff failed to challenge or rebut this belief in any way after it sent the 2012 letter. *Id.* at 6. Defendants further contend that Plaintiff did not elicit any testimony to demonstrate that Defendants' belief was unreasonable. *Id.* Further, Defendants argue that they could not have copied Plaintiff's product because no one from Defendants ever saw or learned about a working Plaintiff product. *Id.* Defendants further argue that they had a [redacted] *Id.*

In its opposition, Plaintiff responds that Defendants misrepresent the holding in *Roche*. ECF No. 220 at 6. Plaintiff argues that the case stands only for the proposition that the acts of ***inducement*** must occur during the damages period.[1] Opp. at 7 (emphasis added). But Plaintiff contends that Defendants may acquire the ***knowledge*** prior to the damages period. *Id.* (emphasis added). Plaintiff argues that, in this case, the evidence demonstrates Defendants had said knowledge as of 2012, which was prior to the damages period. *Id.* The fact that Defendants knew it infringed before 2013 does not change the fact that it also knew it infringed in 2013 and after. *Id.* at 8. Further, Plaintiff argues that if Defendants' interpretation of *Roche* were true, then a notice letter received before the damages period could never be evidence of willfulness, "[n]or would an infringer's planning and intentional development of an infringing product before the

[1] Plaintiff states that while *Roche* focused only on induced infringement, it assumed that *Roche* also applies to willful infringement. Opp. at 7.

damages period ever be relevant to its later infringing acts." *Id.* Finally, Plaintiff argues that Defendants' argument urges the Court to usurp the jury's fact-finding role. *Id.*

Plaintiff responds that there is ample evidence to support the jury's determination of induced and willful infringement. *Id.* at 8. First, Plaintiff asserts that Defendants' instructional videos were distributed to dentists in the United States and they demonstrated the recommended location for the dentists to begin scanning. *Id.* (citing Tr. at 239:21–240:11, 723:22–725:6, 730:3–731:1; Opp., Ex. 8). Second. Plaintiff contends that Defendants confirmed their intent to get dentists to use the Accused Products in accordance with the video. *Id.* at 9 (Tr. at 723:22–725:6). Additionally, Defendants' expert testified that following the video's instructions would result in the origin point of the fixed global reference coordinate system being fixed at a single location within the intra-oral cavity as required by the Court's construction of Claim 37. *Id.* (citing Tr. at 844:4–845:25). Plaintiff also argues that Defendants sold its scanners throughout the damages period. *Id.* (citing Tr. at 920:7–14, 230:23–25, 202:13–203:17, 617:14–618:15; Opp., Ex. 9). Based on that, Plaintiff contends that the jury heard substantial evidence of Defendants' active inducement. *Id.*

With respect to Defendants' argument that they had a reasonable belief that they did not infringe, Plaintiff responds that the jury concluded otherwise based on several potential facts. *Id.* In particular, Plaintiff points to evidence that Defendants viewed the alleged patent infringement as relatively minor (Tr. at 624:15–17), Defendants did not review the accused source code (Tr. at 625:7–627:7), Defendants failed to complete a claim chart after concluding that the first element was present in the accused products (Tr. at 275:9–277:6, 348:8–21; ECF No. 189, Ex. 10), and Defendants did not remediate its infringement, even after commencement of suit (Tr. at 230:23–25, 242:23–243:7; 253:18–21, 304:15–305:13, 306:3–13, 665:15–666:4, 738:3–739:25). *Id.* at 9–

10. Further, Plaintiff argues that a jury could infer a lack of reasonable belief of non-infringement based on Defendants' failure to respond to Plaintiff's 2012 notice letter. *Id.* at 10.

Plaintiff contends that Defendants' argument that the damages should be reduced to $25,452 because the letter only applied to the 2011 product is meritless. *Id.* at 10. In particular, Plaintiff contends that the evidence showed that the 2011 product and the Accused Products "all practice the same method" and "had no differences that 'affect [the] infringement analysis in any way.'" *Id.* (citing Tr. at 300:17–301:18, 242:5–243:7, 253:18–21, 304:15–305:13, 306:3–13, 665:15–666:4, 738:3–739:25). Based on that, Plaintiff asserts that the "jury had substantial evidence to contradict [Defendants'] new argument that it 'had no reason to know'" that the Accused Products operated in the same infringing manner as the 2011 product. *Id.*

In addition, Plaintiff alleges that Defendants' argument is waived for failure to include it in its 50(a) motion and at trial. *Id.*

In their reply, Defendants respond that they do not suggest that the only relevant evidence are acts occurring within the damages period, but rather, like in *Roche*, "a party who sends a notice letter has six years to bring a claim for induced or willful infringement[,]" which Plaintiff failed to do. Reply at 4 (citing 30 F.4th at 1119 (citing 35 U.S.C. § 286)).

Defendants allege that Plaintiff has the burden of proving knowledge and intent, but rather Plaintiff only has shown knowledge and sales. *Id.* Defendants contend that "[j]ust as sales throughout the damages period with instructions to end users were insufficient for inducement in *Roche*, evidence of [Defendants' Accused Product] sales with instructions to end users are insufficient for inducement here." *Id.* (citing *Roche*, 30 F.4th at 1119–20).

With respect to Plaintiff's argument Defendants only prepared a partial claim chart, Defendants argue, that even if true, that "occurred long before the six-year statutory period of 35

U.S.C. § 286 and thus have no applicability here." *Id.* Defendants argue that "[t]he Federal Circuit expressly rejected the 'continuing-impact standard' that [Plaintiff] would need for its evidence of 'intent' to support induced and willful infringement here." *Id.* (citing *Roche*, 30 F.4th at 1120).

Defendants assert that the 2012 notice letter did not provide them with any specific information how they infringed. *Id.* at 5. Defendants further assert that Plaintiff agrees with them, "explaining in its Equitable Estoppel Opposition that 'there was no threat at all in the [Plaintiff's] Notice Letter." *Id.* (citing ECF No. 200 at 8). Based on that, Defendants state that because they "did not have any information about how it allegedly caused end users to infringe and could not have knowingly induced the infringing acts or possessed specific intent to encourage another to infringe in the undisclosed manner[,]" the "letter does not establish intent for either willful or induced infringement." *Id.*

With respect to their argument that the damages should be reduced to $24,452, Defendant contends that Plaintiff has not carried their burden of proving damages by failing to "provide any evidence that [Defendants'] was on notice that its products released after the 2012 letter infringed." *Id.* Defendants contend that instead of doing so, Plaintiff "does not identify any products, does not explain why [Defendants] infringe[], and [the notice letter] was sent before the damages period began." *Id.* Defendants further contend that without that detail because Plaintiff "failed to include any details of [Defendants'] alleged infringement in the letter, Defendants has no way of know if their products infringed[.]" *Id.*

With respect to Plaintiff's waiver argument, Defendants assert that it fails because "[Plaintiff's] argument that the only product that [the] notice letter applies to relies on the same evidence and law that supported its Rule 50(a) motion for judgment as a matter of law regarding

induced infringement (no knowledge) and willful infringement (no specific intent)." *Id.* (citing *Taylor Publ'g Co. v. Jostens Inc.*, 216 F.3d 465, 473-74 (5th Cir. 2000)).

The Court's Analysis:

The Court agrees with Plaintiff that recovery in this case is not barred by 35 U.S.C. § 286. First, Defendants' interpretation of the holding in *Roche* is incorrect. The court in *Roche* held that the ***inducing acts*** must take place during the damages period, but not that ***evidence of knowledge*** must do so as well. More practically, it does not stand to reason that knowledge would simply vanish because it was acquired before the statutory period. Therefore, the March 2012 letter was legally valid evidence, upon which the jury could rely in making their decision.

With respect to whether there is substantial evidence for the jury to conclude that Defendants induced infringement or willfully infringed, the Court agrees with Plaintiff that there was, *e.g.*, instructional videos, Defendants confirmed their intent to get dentists to use the Accused Products in accordance with the video, Defendants' expert testified that following the video's instructions would result in the origin point of the fixed global reference coordinate system being fixed at a single location within the intra-oral cavity, *etc.* Tr. at 239:21–240:11, 723:22–725:6, 730:3–731:1; Opp., Ex. 8; Tr. at 844:4–845:25.

With respect to whether there is substantial evidence for the jury to conclude that Defendants did not have a reasonable belief that they did not infringe, the Court agrees with Plaintiff that there was, *e.g.*, that Defendants viewed the alleged patent infringement as relatively minor, Defendants did not review the accused source code, *etc.* Tr. at 624:15–17, 625:7–627:7; ECF No. 189, Ex. 10.

With respect to Defendants' argument that the damages should be reduced to $25,452 because the notice letter only applied to the 2011 product, the Court agrees Plaintiff that there is substantial evidence that the Accused Products operated in the same infringing manner as the 2011 product. Tr. at 300:17–301:18, 242:5–243:7, 253:18–21, 304:15–305:13, 306:3–13, 665:15–666:4, 738:3–739:25

C. Whether the Accused Products meet all claim limitations

Defendants argue that the accused products do not meet several claim limitations. Mot. at 7–14.

1. Whether "mobile registration device" meets the requirements of Claim 37(c)

Defendants argue that Plaintiff's expert opined that the [redacted] was the "mobile registration device" of Claim 37(c) and [redacted]" Mot. at 7 (citing Tr. at 340:24–341:9, 344:16–345:19, 387:1–12). Defendant further argues that Plaintiff's expert opined that the [redacted] of the Accused Product—and not the [redacted] *Id.* (citing Tr. at 306:3–13, 340:12–345:19, 387:1–12). Defendants argue that Plaintiff's infringement theory is insufficient to establish infringement for three reasons: (1) [redacted] (2) [redacted] (3) [redacted]

With respect to the first reason, Defendants argue that while Plaintiff's expert opined that [redacted] *Id.* (citing Tr. at 344:16–345:19, 387:8–23) (emphases in Defendants' brief). Defendants assert that this is not surprising as "the record conclusively establishes the [the

[redacted] *Id.* (citing Tr. at 601:17–602:8, 658:3–660:18, 678:24–681:1, 797:1-15).

With respect to the second reason, Defendants allege that Plaintiff did not prove that the [redacted] *Id.* Rather, Defendants argue that "[t]he only evidence of record establishes that the [redacted] *Id.* (citing Tr. 387:1–7; 341:4–9, 666:5–668:11).

Finally, with respect to the third reason, Defendants contend that while the claim language requires "recording global positions and orientations of the measuring and imaging *device*," Plaintiff's infringement theory "record[s] global positions and orientations of 3D *images*." *Id.* (emphases in Defendants' brief). Defendants assert that "images" cannot be a "device" and Claim 37 recites both. *Id.* at 8–9 (citing Tr. at 369:18–372:22). In addition, Defendants contend that while the claim language requires that the "mobile registration device" records the global position and orientation, the [redacted] the alleged "mobile registration device," [redacted] *Id.* at 9 (citing Tr. at 386:21–25). Furthermore, Defendants contend that Plaintiff's infringement theory improperly conflates "3D images (data acquired by a scanner) with the scanner itself (*i.e.*, the device acquiring the data)[.]" *Id.*

In its opposition, Plaintiff responds that there was "ample evidence that the [redacted] .]" Opp. at 11. Plaintiff argues that Defendants' own witnesses "testified that the [redacted]



Id. (citing Tr. at 259:8–13; Opening, Ex. 11 at 17519; Tr. at 240:20–241:25). Plaintiff argues that a jury was entitled to conclude, based on opinions of Plaintiff's expert which were based on this evidence, other documents, and his source code analysis, that "the *scanner's* global position and orientation were indeed recorded." *Id.* (citing Tr. at 306:3–13, 310:19–311:12, 339:18–347:16, 355:7–356:23, 362:19–367:2, 371:13–372:22, 376:15–378:6, 378:18–380:4, 386:13–388:4) (emphasis in Plaintiff's brief).

Contrary to Defendants' argument, Plaintiff asserts that its infringement theory for the "mobile registration device" [redacted] *Id.*at 11–12 (citing Tr. at 341:10–17, 253:10–17, 340:12–20, 303:11–304:25, 341:10–342:4, 386:21–25, 754:10–755:19, Opp., Exs. 2, 12, 13, 14; Tr. at 386:6–25). Plaintiff argues that Defendants' expert also confirmed that the [redacted] *Id.* at 12 (citing Tr. at 754:10–755:19).

Plaintiff contends that Defendants' argument effectively rewrites the claim language to require the mobile registration device itself to perform the recording, whereas the claim language only requires that mobile registration device be used "for" the measuring and recording process. *Id.* at 12. Plaintiff also contends that Defendants' argument is untimely and an "improper post-

verdict claim construction argument[.]" *Id.* (citing *Lazare Kaplan Int'l v. Photoscribe Techs.*, 628 F.3d 1359, 1376 (Fed. Cir. 2010)).

Plaintiff states that the specification "makes it clear" the mobile registration unit can work with other system components (e.g., CPPU 42 located outside of the patient's mouth) and that the mobile registration device *enables* measuring and recording, for example, by transmitting "data suitable for enabling recording of positions of a measuring and imaging device with respect to intra-oral fixed global registration position 28." *Id.* at 12–13 (citing '707 Patent at 17:11–14, 18:10–23) (emphasis in Plaintiff's brief).

Plaintiff asserts that there is substantial evidence that directly conflicts with Defendants' argument that the recordings were not of "global" orientations and positions. *Id.* at 13. In particular, Plaintiff contends that its expert testified that the Accused Products capture [redacted] *Id.* (citing Tr. at 306:3–13, 309:18–25, 339:23–340:11, 340:24–342:4, 342:23–343:9, 344:1–345:19). Plaintiff further contends Defendants' witnesses testified [redacted] which supported its expert's testimony. *Id.* at 14 (citing Tr. at 236:20–25, 239:12–17, 241:1–7, 242:5–20, 243:8–14, 243:21–25, 251:2–6, 342:5–343:13, 668:12–14, 739:22–24, 756:11–757:1).

Plaintiff argues that its expert testified that the Accused Products' "[redacted] include a "[redacted] that converts local position and orientation information into a global coordinate space. *Id.* (citing Tr. at 344:2–8, 553:9–212). Plaintiff further argue that Defendants admit that the Accused Products use "[redacted] to "[redacted] *Id.* (citing

Tr. at 310:19–311:9, 739:22–24). Plaintiff states that the Defendants' expert and one of Defendants' employees confirmed that [redacted] *Id.* (citing Tr. at 754:3–757:1, 738:21–739:9, 242:23–243:3, 254:21–23, 255:14–17, 242:23–243:7).

Plaintiff calls Defendants' argument that "3D images are not a device" a "strawman." *Id.* More specifically, Plaintiff asserts that the fact that [redacted] *Id.* at 14–15. Plaintiff argues that the evidence in the record supports its assertion. *Id.* (citing Tr. at 259:10–13, 345:20–347:13, Opp., Ex. 13 at 17519, Tr. at 240:20–241:25, 376:22–377:22, 339:18–24, 340:7–8, 342:22, 343:19–345:8).

With respect to Defendants' argument that Plaintiff's infringement theory improperly conflates 3D images with the scanner itself, Plaintiff argues that this is a new post-trial claim construction argument and thus Defendants have waived it. *Id.* at 15, n.9 (citing *Lazare Kaplan*, 628 F.3d at 1376).

In its reply, Defendants argue that Plaintiff improperly reads the 'measuring and imaging device' as directed to scan data, not a scanner. Reply at 6. Defendants state that while Plaintiff "relied exclusively on evidence of [the Accused Products] [redacted] it "now tries to justify conflating these elements by arguing they are related, [but] the *scanner* and *3D scan data* are distinct claim limitations. *Id.* (emphases in Defendants' brief). Defendants assert that the [redacted] but Plaintiff's expert "acknowledged that he does not 'know where and how [Defendants] produced" that picture. *Id.* (citing Tr. at 379:1–12). Defendants argue that the evidence Plaintiff cites indicates that the [redacted] is generated from the [redacted] and

[redacted] *Id.* at 6–7 (citing Tr. at 240:20–241:25, 259:8–23, 750:8–15, 865:5–866:2, 341:10–343:9, 310:19–311:12, 344:1–15).

Defendants further argue that Plaintiff did not show recording global positions and orientations. *Id.* at 7. More specifically, Defendants state that while Claim 37 requires that the mobile registration device records both global positions and global orientations, Plaintiff's expert explained that the [redacted] *Id.* (citing Tr. at 304:13–305:13, 386:21–25, 387:18–23). Defendants further assert that Plaintiff's expert "never tied the [redacted] and therefore Dr. Bajaj's actual testimony contradicts [Plaintiff's] new post-trial infringement theory and cannot support a finding of infringement." *Id.* at 7–8 (citing *ParkerVision, Inc. v. Qualcomm Inc.*, 627 Fed. App'x. 921, 923-24 (Fed. Cir. 2015)).

The Court's Analysis:

The Court agrees that there is substantial evidence for the jury to conclude that the Accused Products meet the disputed limitations in Claim 37(c). ***First***, with respect to whether there was there is recording of global position, there is evidence from Defendants' own witnesses that the [redacted] shows [redacted]" which is evidence of a global position being recorded. Tr. at 259:8–13 (discussing Opening, Ex. 11 at 17519); *see also* Tr. at 240:20–241:25. While Defendants argue that the [redacted] represents the [redacted] there obviously is a relationship between the [redacted] and the [redacted] so, at most, the [redacted] Furthermore, Plaintiff's expert provided testimony that the Accused Products record a global

position. Tr. at 306:3–13, 310:19–311:12, 339:18–347:16, 355:7–356:23, 362:19–367:2 (source code discussion), 371:13–372:22, 376:15–378:6, 378:18–380:4, 386:13–388:4.

Second, with respect to Defendants' argument that Plaintiff's expert only identified the [redacted] as the "mobile registration device," Plaintiff's expert actually identified [redacted] *See, e.g.*, Tr. at 34:12–20. With respect to Defendants' argument that the [redacted], Plaintiff's expert explained that the Accused Products convert [redacted] so there is substantial evidence for a jury to conclude that the mobile registration device records the global position. *See, e.g.*, Tr. at 339:17–340:11, 344:1–15.

Third, with respect to whether there is recording of global orientation, Plaintiff's expert testified that the mobile registration device did so. *See, e.g.*, Tr. at 306:3–13, 339:23–340:11, 340:24–342:4, 342:23–343:9, 344:1–345:19. Furthermore, Defendants' witnesses testified that the [redacted] Tr. at 236:20–25, 243:8–14, 243:21–25, 342:5–343:13, 739:22–24, 756:11–757:1).

Fourth, with respect to whether 3D images are a device, the Court agrees with Plaintiff that Defendants' argument is a strawman as it is not an either/or situation where only one of (1) the [redacted] or (2) the [redacted]

Fifth, because Defendants do not dispute that they failed raise this argument in the past, Defendants have waived this argument.

Therefore, for the reasons described above, the Court concludes there is substantial evidence for the jury to conclude that Claim 37(c) was infringed.

2. Whether position and orientation is recorded "relative to same said intra-oral fixed global registration position"

Claim 37 also requires that the "global positions and orientations" are measured and recorded "relative to same said intra-oral fixed global registration position."

Defendants argue that Plaintiff's expert points to the (1) [redacted] and (2) [redacted] to meet this limitation. Mot. at 10 (citing Tr. at 654:21–655:18, 658:3–17, 338:1–12, 340:12–343:9). With respect to the former, Defendants assert that the [redacted] *Id.* With respect to the latter, Defendants assert that [redacted] *Id.* (citing Tr. at 693:10–13, 789:25–790:24, 794:4–18, 834:3-25).

In its opposition, Plaintiff responds that Defendants make two incorrect assertions in their arguments, namely, that (1) Plaintiff relied only on the [redacted] to meet the limitations of Claim 37(c) and (2) that the intra-oral fixed global registration position limitation is not met because it is established in part by using a [redacted] With respect to the former, Plaintiff asserts that its expert identified [redacted] With respect to the latter, Plaintiff explains in Section III.C.4 that this is incorrect because it improperly seeks to distinguish the "intra-oral fixed global registration position" from the [redacted] *Id.* at 16–18.

In its reply, Defendants state that Plaintiff points to no evidence for this limitation. Reply at 8.

The Court's Analysis:

The Court agrees with Plaintiff that there is substantial evidence that the global position and orientation is recorded "relative to same said intra-oral fixed global registration position." First, as described above, Plaintiff's expert did not only rely on the [redacted] for his infringement theory, but identified [redacted]. Tr. at 341:10–17, 340:12–20.

Second, with respect to the [redacted] (*i.e.* alleged fixed global registration position), the Court provides its analysis in Section III.C.4 below.

3. Whether the Accused Products "record a global position of said measuring and imaging device relative to said intra-oral fixed global registration position" as required by Claim 1

Defendants contend that Plaintiff's expert again improperly conflates "global position" of the 3D images with that of the scanner. Mot. at 10 (citing Tr. at 347:23–348:13; 355:6–356:15). More specifically, Defendants contend that "if the 'recording of said global position of said measuring and imaging *device*' is read on the global position of the 3D *images*, it would render superfluous the subsequent limitation of 'forming at least one globally recorded three-dimensional measurement and image.'" *Id.* (emphases in Defendants' brief).

In its opposition, Plaintiff responds that Defendants' argument is based on a mischaracterization of Plaintiff's expert's testimony. Opp. at 16. More specifically, Plaintiff asserts that while Defendants conflate [redacted] its expert "explicitly distinguished" the two. *Id.* (citing Tr. at 343:19–344:15). Plaintiff states that [redacted]. *Id.* (citing Tr. at 343:19–345:8, 356:7–21). Plaintiff states that Defendants' expert agrees with its position. *Id.* (Tr. at 630:14–20).

In its reply, Defendants argues that, as was the case for Claim 37, Plaintiff conflates the [redacted] with the claimed recording the position of the scanner. Reply at 8.

The Court's Analysis:

The Court agrees with Plaintiff that there is substantial evidence that the Accused Products "record a global position of said measuring and imaging device relative to said intra-oral fixed global registration position." As described in Plaintiff's opposition (and not disputed in Defendants' reply), Defendants' argument conflates [redacted], but Plaintiff's expert did not conflate the two, but rather distinguished them. Tr. at 343:19–344:15. In particular, Plaintiff's expert described that a [redacted] Tr. at 343:19–345:8.

4. Whether the Accused Products meet the "intra-oral fixed global registration position" limitation

The Court construed "intra-oral fixed global registration position" to require "a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system." ECF No. 160 at 1.

Defendants argue that although Plaintiff alleged the "'center of mass of the first subscan' met the 'intra-oral fixed global registration position' limitation, it failed to show that the center of mass 'relat[ed] multiple sets of three-dimensional data' as required by the Court's construction." Mot. at 11 (citing Tr. at 317:7–13, 373:11–374:8). Rather, Defendants argue that Plaintiff's expert argued that a different claim element–[redacted] *Id.* (citing Tr. at 317:17–318:24, 373:24–374:25). Defendants contend that Plaintiff's expert "attempts to conflate [redacted] (*i.e.* alleged fixed global registration

position) with the [redacted] (*i.e.* alleged origin point in the 'fixed global reference coordinate system') would render superfluous these separate limitations under the Court's construction." *Id.* (citing Tr. at 322:4–323:4).

In its opposition, Plaintiff responds that it is not improperly conflating the [redacted]; rather, the two are simply the same. Opp. at 17. Plaintiff argues that the Court's constructions do not in any way require that the two positions be different locations. *Id.* at 18. Rather, Plaintiff contends that "[u]sing the fixed registration position as the origin of the coordinate system is the most natural place for it" and is perfectly consistent with the Court's constructions. *Id.* Plaintiff assert that because there is substantial evidence to support a conclusion that Defendants' products meet the claim limitation, the jury's decision should be respected. *Id.*

In its reply, Defendants responds that "[u]nder the Court's construction, there must be two distinct points[,]" but Plaintiff's "infringement theory ignores the constructions requiring two fixed points." Reply at 8–9. Defendants argue that their position is that "it is the fixed point associated with the "intra-oral fixed global registration position" that must be used to relate the multiple sets of data. Showing that the fixed global reference coordinate system has an origin cannot substitute for proof that this claim element is present." *Id.* at 9.

The Court's Analysis:

The Court agrees with Plaintiff that there is substantial evidence to warrant a conclusion that the Accused Products meet the claimed "intra-oral fixed global registration position" for at least the following reasons. ***First***, the Court's constructions do not mean that the origin of the coordinate system cannot be located at the same point as the fixed global registration position. As

described above, the Court's construction for "intra-oral fixed global registration position" only requires "a fixed position inside the oral cavity that is used as a reference point for relating multiple sets of three-dimensional data to a fixed global reference coordinate system." ECF No. 160 at 1. The Court further construed that the plain and ordinary meaning of "a fixed global reference coordinate system" includes an "origin point [that] is fixed at a single location within the inter-oral cavity." ECF No. 160 at 1. Plaintiff correctly notes that this construction only requires that an origin of such a coordinate system is a fixed point within the mouth, and not also a fixed point other than the fixed global registration position. Opp. at 18.

Second, in addition to the fact that the Court's constructions do not mean that the origin of the coordinate system cannot be located at the same point as the fixed global registration position, the Court agrees with Plaintiff that the "fixed registration position as the origin of the coordinate system is the most natural place for it [.]" *Id.*

5. Whether Plaintiff's other infringement positions are legally proper

The Parties' Arguments regarding Claim 37(b):

Defendants argue that Plaintiff's infringement position regarding Claim 37(b) ("measuring and imaging device for measuring and imaging . . . **relative to** same said intra-oral fixed global registration position") is legally improper. Opening at 13 (emphasis in Defendants' brief). In particular, Defendants argue that Plaintiff's expert failed to provide an opinion regarding the "relative to" language from Claim 37(b) in his expert report, but instead provided a new opinion by testifying that his analysis for Claims 1(b) and 1(d) also applied to Claim 37(b). *Id.* Defendants argue that is "simply untrue" as Claim 1 does not require "measuring and imaging . . . relative to same said intra-oral fixed global registration position." *Id.*

Defendant further argues that Plaintiff failed to show that the alleged "measuring and imaging" in the Accused Products occurs "relative" to the alleged "intra-oral fixed global registration position" (*i.e.* the center of mass of the first subscan). *Id.* (citing Tr. at 317:7–13). Defendants argues that Plaintiff's lack of evidence is because the "center of mass is temporary and only used to register the first subscan, and therefore cannot be measured or imaged relative to as required by the claims." *Id.*

In its opposition, Plaintiff responds first that Defendants waived this argument because they did not include it in their Rule 50(a) motion. Opp. at 19. Plaintiff further argues that there is substantial evidence to support a finding that the Accused Products contain "a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity, relative to same said intra-oral fixed global registration position[.]" *Id.* (citing Tr. at 325:7–328:1, 336:9–339:16; Exs. 15, 8, 16, 1; Tr. at 750:24–752:13, 725:17–726:11).

In its reply, Defendants argue that Plaintiff's infringement theory "conflates the 'intra-oral fixed global registration position' with the 'fixed global reference coordinate system.'" Reply at 9.

The Court's Analysis regarding Claim 37(b):

As a preliminary matter, the Court believes that Defendants waived this argument, as demonstrated by failing to address it in their reply.

With respect to the merits, the Court agrees that the Plaintiff's infringement position regarding Claim 37(b) is legally proper. With respect to Defendants' argument that Plaintiff's infringement theory "conflates the 'intra-oral fixed global registration position' with the 'fixed global reference coordinate system,'" the Court addressed this argument in Section III.B.4 above.

Furthermore, there is substantial evidence for a jury to find infringement of Claim 37(b). Plaintiff's expert testified that "the position and orientation . . . is always transferred to the global coordinate space where it's *relative to* that same intra-oral fixed global registration position." *See, e.g.,* Tr. at 325:7–328:1, 336:9–339:16; Exs. 15, 8, 16, 1; Tr. at 750:24–752:13, 725:17–726:11 (emphasis added).

The Parties' Arguments regarding Claim 1(f):

Defendants argue that Plaintiff's infringement position regarding Claim 1(f) ("registering local coordinate space pixel positions in each of ***said*** plurality of globally recorded three-dimensional measurements and images…. .") is also legally improper. Opening at 13 (emphasis in Defendants' brief). More specifically, Defendants argue that the preceding limitations describe the formation of the 3D images, which are registered in Claim 1(f). *Id.* at 13–14. But Defendants argue that Plaintiff's expert's infringement theory uses already-registered images to meet prior limitations, so there is no registration of **said** plurality of globally recorded three-dimensional measurements and images" (i.e., those formed in the preceding limitations), which ultimately renders Claim 1(f) to be superfluous. *Id.* at 14.

In its opposition, Plaintiff notes that Defendants' argument does not argue that there is insufficient evidence to conclude that the Accused Products practiced Claim 1(f); only that Plaintiff's infringement theory for the preceding limitations renders Claim 1(f) to be superfluous. Opp. at 19. Plaintiff contends that Defendants' argument is either a claim construction or invalidity argument, which are both waived at this point in the case. *Id.* Plaintiff contend that Defendants are incorrect in their interpretation of Claim 1(f). *Id.* More specifically, Plaintiff contend that Claim 1(f) addresses the registration of "local coordinate space pixel positions," which are not

"claimed or implicated" in elements 1(d) or 1(e). *Id.* In any event, Plaintiff contends that its expert provided substantial evidence to support the jury's finding of infringement. *Id.* at 20 (citing Tr. at 357:20–359:18; Exs. 17, 8).

In its reply, Defendants argue that there is "no evidence that the alleged 3D measurements and images are globally recorded, and conclusory testimony is legally insufficient." Reply at 9.

The Court's Analysis regarding Claim 1(f):

The Court agrees that the Plaintiff's infringement position regarding Claim 1(f) is legally proper. In particular, the Court agrees with Plaintiff that Claim 1(f) addresses the registration of "local coordinate space pixel positions," which are not "claimed or implicated" in elements 1(d) or 1(e). Claims 1(d) and 1(e) recite acquiring "globally recorded three-dimensional measurements and images," but do not mention "local coordinate space pixel position." Therefore, contrary the Defendants' argument, Plaintiff's infringement theory does not render Claim 1(f) to be superfluous.

In any case, there is substantial evidence to support the jury's finding of infringement. Tr. at 357:20–359:18; Exs. 17, 8.

D. Whether equitable estoppel bars Plaintiff's claims of patent infringement or relief

Defendants argue that equitable estoppel bars Plaintiff's claims of patent infringement and relief. Mot. at 14. Defendants filed a separate brief on this issue, Plaintiff opposed, and Defendants replied. ECF Nos. 192, 200, 205. The Court entered its Findings of Fact and Conclusions of Law Regarding Equitable Estoppel on April 24, 2024. ECF No. 242.

E. Whether damages award is based on legally flawed testimony and principles

Defendants argue that Plaintiff's damages expert's "analysis fails to perform any apportionment and is otherwise so flawed that the Court should find that it provides no support to the verdict." Opening at 15. Defendants' JMOL regarding damages heavily overlaps with Defendants' Motion for New Trial. *Id.* at 15 ("As discussed in more detail in [Defendants'] Motion for a New Trial…"), 18 (citing ECF. No . 194 (Defendants' Motion for New Trial)), 20 (same). The Court denied Defendants' Motion for New Trial on August 25, 2025. ECF No. 247.

Defendants argue that Plaintiff's expert's damages theory has several shortcomings. Opening at 15–17. The Court summarized the parties' descriptions of Plaintiff's expert's damages theory in its Order Denying Defendants' Motion for New Trial, which the Court incorporates herein. ECF No. 247 at 31–45.

Defendants first argues that the damages award "should be corrected to reflect the 'incremental *profit*' theory that [Plaintiff's damages expert] presented to the jury." Opening at 17 (citing Tr. at 419:10–14). In particular, Defendants contend that Plaintiff's damages expert did not apply the costs to make and sell products to his "price premium analysis." *Id.* Defendants argue that applying the costs would reduce the maximum damages for the "price premium" from $22.6M to $3.7M. *Id.* at 17–18 (citing Tr. at 915:9–17, 917:7–23).

Defendants next argue that there is no evidence to support Plaintiff's damages theory. *Id.* at 18–20. More specifically, Defendants argue that (1) Plaintiff's damages expert failed to apportion, (2) there is no evidence that the Asserted Patent has any impact on the accuracy of the Accused Products, and (3) Plaintiff's damages expert "comparison of two products that have an entirely uncertain relationship to the [Asserted Patent] cannot support an opinion that customers would pay more for 'accuracy,' much less that customers would pay more for the '707 patent's

invention." *Id.* at 18–20, 20, 20 (citing *ResQNet.com, Inc. v. Lansa, Inc.*, 594 F.3d 860, 869 (Fed. Cir. 2010)). Defendants expressly cites to their Motion for New Trial for each of these arguments. *Id.* at 18, 20, 20. The Court summarized each of these arguments in its Order Denying Defendants' Motion for New Trial, which the Court incorporates herein. ECF No. 247 at 31–34, 37–41; *see also* ECF No. 247 at 42–44.

In its opposition, Plaintiff asserts that Defendants' argument is a renewed *Daubert* motion. Opp. at 20. Plaintiff argues that the jury's damages award was "supported by the legally sound, and more-than-sufficient testimony" of Plaintiff's damages expert. *Id.* (citing ECF No. 219 (Plaintiff Response to Defendant's Post Trial Motion for New Trial Pursuant to Rule 59) at § III(D)). Plaintiff asserts that "a jury's damages award 'must be upheld unless the amount is grossly excessive or monstrous, clearly not supported by the evidence, or based only on speculation or guesswork.'" *Id.* (citing *Brooktree Corp. v. Advanced Micro Devices, Inc.*, 977 F.2d 1555, 1580 (Fed. Cir. 1992)). Plaintiff argues that its damages expert "sufficiently tied his analysis to the facts of the case—most of which were based on [Defendants'] own data—and opined only to damages attributable to [Defendants'] use of the [Asserted Patent]." *Id.* (citing ECF No. 219 (Plaintiff Response to Defendant's Post Trial Motion for New Trial Pursuant to Rule 59) at § III(D)). Based on that, Plaintiff argues that the "jury had substantial evidence upon which to find its $11.875 million damages award." *Id.*

In its reply, Defendants argue that they are "not improperly rehashing a *Daubert* motion." Reply at 10. Rather, pursuant to *Brooktree*, Defendants contend that:

> The damages awarded are grossly excessive because [Plaintiff] failed to apportion, used [Defendants']list prices instead of actual prices, and called [Defendants'] revenue its profit, and led this Court to err in excluding testimony that [Defendants] could have designed around the patent for $10,000. There is no evidence whatsoever that the [Asserted Patent] improves the "accuracy" of the accused products. The only evidence is that the [Asserted Patent] helps with accuracy, but

> there was no evidence that it contributes at all to the accuracy of the accused products, and if so, how much. [Plaintiff's damages expert's] damages theory relies on the monetary value of "accuracy" and fails to link the value of the patent and the accused products. Finally, the only evidence that the market would pay more for "accuracy" is [Plaintiff's damages expert's] testimony about the Omnicam and Bluecam devices. But [Plaintiff's damages expert] confirmed that he does not know whether either practice the [Asserted Patent]. The "evidence" that the market would pay more for use of the [Asserted Patent] is based on nothing but speculation and guesswork.

Id.

The Court's Analysis:

With respect to Defendants' argument that the Court should reduce the jury's damages award to $3.7M because Plaintiff's damages expert failed to consider Defendants' costs, the Court disagrees with Defendants. As described in the Court's Order Denying Defendants' Motion for New Trial, Plaintiff's damages expert used "Defendants' financial data to determine the profit margins and that he testified how he considered costs in his analysis." ECF No. 247 at 42–43 (citing Tr. at 457:1–459:25; ECF No., 194, Ex. 24); *see also* ECF No. 247 at 45. As described in that Order, the Court concludes there is substantial evidence to support the jury's verdict. The Court incorporates that analysis into this Order. Therefore, the Court denies Defendants' request to reduce the damages to $3.7M.

With respect Defendants' three arguments that there is no evidence to support Plaintiff's damages theory, the Court again disagrees. The Court considered each of these arguments in its Order Denying Defendants' Motion for New Trial. *Id.* at 34–36, 41–42; *see also id.* at 44–45. As described in that Order, the Court concludes there is substantial evidence for each of these arguments to support the jury's verdict. The Court incorporates that analysis into this Order. Because the jury's damages award was not "grossly excessive or monstrous, clearly not supported

by the evidence, or based only on speculation or guesswork[,]" the Court denies Defendants' request to enter directed verdict on damages. *Brooktree*, 977 F.2d at 1580.

IV. CONCLUSION

In conclusion, for the reasons described herein, the Court **DENIES** Defendants' Renewed Motion for Judgment as a Matter of Law.

SIGNED this 30th day of October, 2025.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

DENSYS LTD.,	§	
	§	
Plaintiff,	§	
v.	§	
	§	
3SHAPE A/S, 3SHAPE TRIOS A/S,	§	Civil Action No. 6:19-cv-00680-ADA
	§	
Defendants.	§	
	§	

FINAL JUDGMENT

This action came before the Court for a jury trial commencing on April 4, 2022, between Plaintiff Densys Ltd. ("Densys") and Defendants 3Shape A/S and 3Shape Trios A/S (collectively, "3Shape"). The issues were tried, and the jury rendered its unanimous verdict on April 8, 2022. Dkt. No. 186. Additionally, this action came before the Court for a bench trial commencing on September 18, 2023. The issues were tried before the Court, and the Court denied all equitable relief sought by the Defendants in findings of fact and conclusions of law entered on April 24, 2024. Dkt. No. 242. The parties filed post-trial motions (Dkt. Nos. 189, 192, 193, 194), all of which have now been decided.

In accordance with the jury verdict, the Court's rulings at trial and on the parties' post-trial motions (Dkt. Nos. 242, 247, 250, and 257), it is hereby **ORDERED** and **ADJUDGED** that:

1. 3Shape infringed Claims 1 and 37 of U.S. Patent No. 6,402,707 (the "'707

Patent").

2. 3Shape induced others to infringe Claims 1 and 37 of the '707 Patent.

3. 3Shape's infringement of Claims 1 and 37 of the '707 Patent has been willful.

4. Judgment is hereby entered in favor of Densys and against 3Shape in the sum of $17,868,182.00 + ($1,371.56 per day from February 14, 2026, up until final judgment). An amount that is the total of:

a. $11,875,000 in damages for infringement before the verdict as awarded by the jury (Dkt. No. 186);

b. $2,968,750 in enhanced damages on the jury verdict (Dkt. No. 257); and

c. $3,024,432 in pre-judgment interest from November 26, 2013, through February 13, 2026, at the T-bill rate, compounded annually, on the jury's compensatory damages award (*i.e.*, $11,875,000), plus $1,371.56 per day from February 14, 2026, up until final judgment.[1]

5. The filing of the Report on Patent/Trademark sent to U.S. Patent and Trademark Office (Dkt. No. 243) was not an entry of judgment in this action, and the Court finds that Densys has not waived its entitlement to costs. Pursuant to Federal Rule of Civil Procedure 54(d), Local Rule CV-54, and 28 U.S.C. § 1920, Densys is the prevailing party in this case and shall recover its allowed costs from 3Shape. It is hereby

[1] $1,371.56= ($11,875,000 [compensatory damage award] + $3,024,432 [pre-judgement interest]) x ((1 + 3.36 % [T-bill rate as of February 13, 2026]) ^ 1 – 1) / 365.

ORDERED that Densys shall submit its Bill of Costs following entry of final judgment by the Court.

6. Densys is additionally awarded post-judgment interest on the entire judgment amount at the statutory rate computed daily and compounded annually (*see* 28 U.S.C. § 1961) from the date of entry of judgment until the date of payment by 3Shape. For avoidance of doubt, that statutory rate is 3.43%.

7. The Court **DENIES** all relief not granted in this judgment. All other claims, counterclaims, and defenses not specifically addressed herein are denied.

This is a final judgment.

SIGNED this 20th day of February, 2026.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

US006402707B1

(12) **United States Patent**
Ernst

(10) **Patent No.: US 6,402,707 B1**
(45) **Date of Patent: Jun. 11, 2002**

(54) **METHOD AND SYSTEM FOR REAL TIME INTRA-ORALLY ACQUIRING AND REGISTERING THREE-DIMENSIONAL MEASUREMENTS AND IMAGES OF INTRA-ORAL OBJECTS AND FEATURES**

(75) Inventor: **Maurice M. Ernst**, Jerusalem (IL)

(73) Assignee: **Denupp Corporation BVI**, Tortolla (VG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/605,679**

(22) Filed: **Jun. 28, 2000**

(51) **Int. Cl.**[7] **A61B 5/103**; A61B 5/117
(52) **U.S. Cl.** **600/590**; 433/214; 433/29
(58) **Field of Search** 600/590, 587, 600/414, 417, 425, 426, 443; 433/29, 25, 213, 214, 215

(56) **References Cited**

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6,008,905	A	12/1999	Breton et al.	

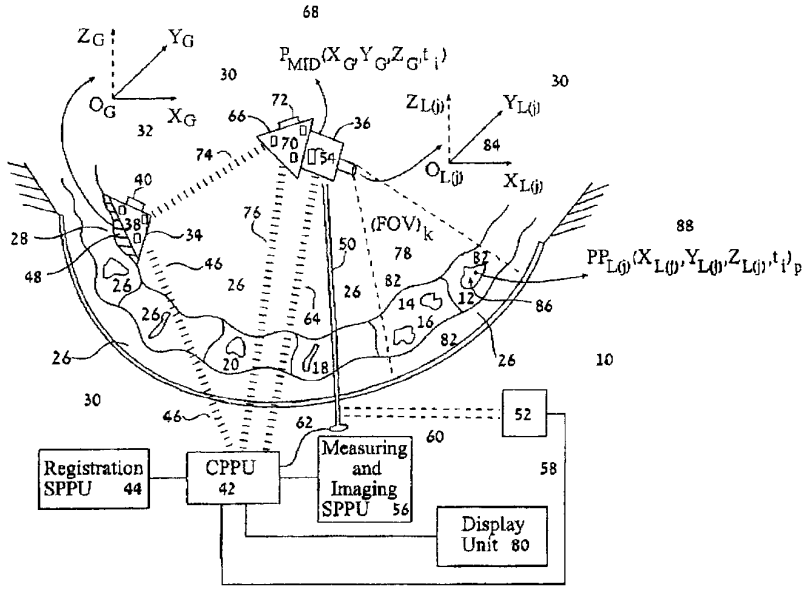
* cited by examiner

Primary Examiner—Kevin Shaver
Assistant Examiner—Brian Szmal
(74) *Attorney, Agent, or Firm*—Lilling & Lilling P.C.

(57) **ABSTRACT**

A method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features. An intra-oral fixed global registration position is established inside the oral cavity of a dental patient, enabling real time acquiring measurements and images of intra-oral objects and features located in multiple fields of view of a measuring and imaging device positioned at various locations in the oral cavity of a dental patient, and recording global positions of the measuring and imaging device relative to the same intra-oral fixed global registration position, where the intra-oral fixed global registration position need not be in any particular field of view of measured and imaged intra-oral objects and features. Local coordinate space pixel positions of acquired and globally recorded measurements and images are registered with global coordinate space pixel positions located in global coordinate space, for forming measurements and images which are all registered with respect to the same intra-oral fixed global registration position in global coordinate space of the oral cavity of the dental patient. Accurate and precise panoramic intra-oral measurement and imaging data and information can be obtained and used in basic and advanced dental applications, whereby measurements and images from multiple fields of view are merged together for forming composite measurements and images, or maps, of the intra-oral objects and features, which can be displayed and stored for further use.

68 Claims, 1 Drawing Sheet



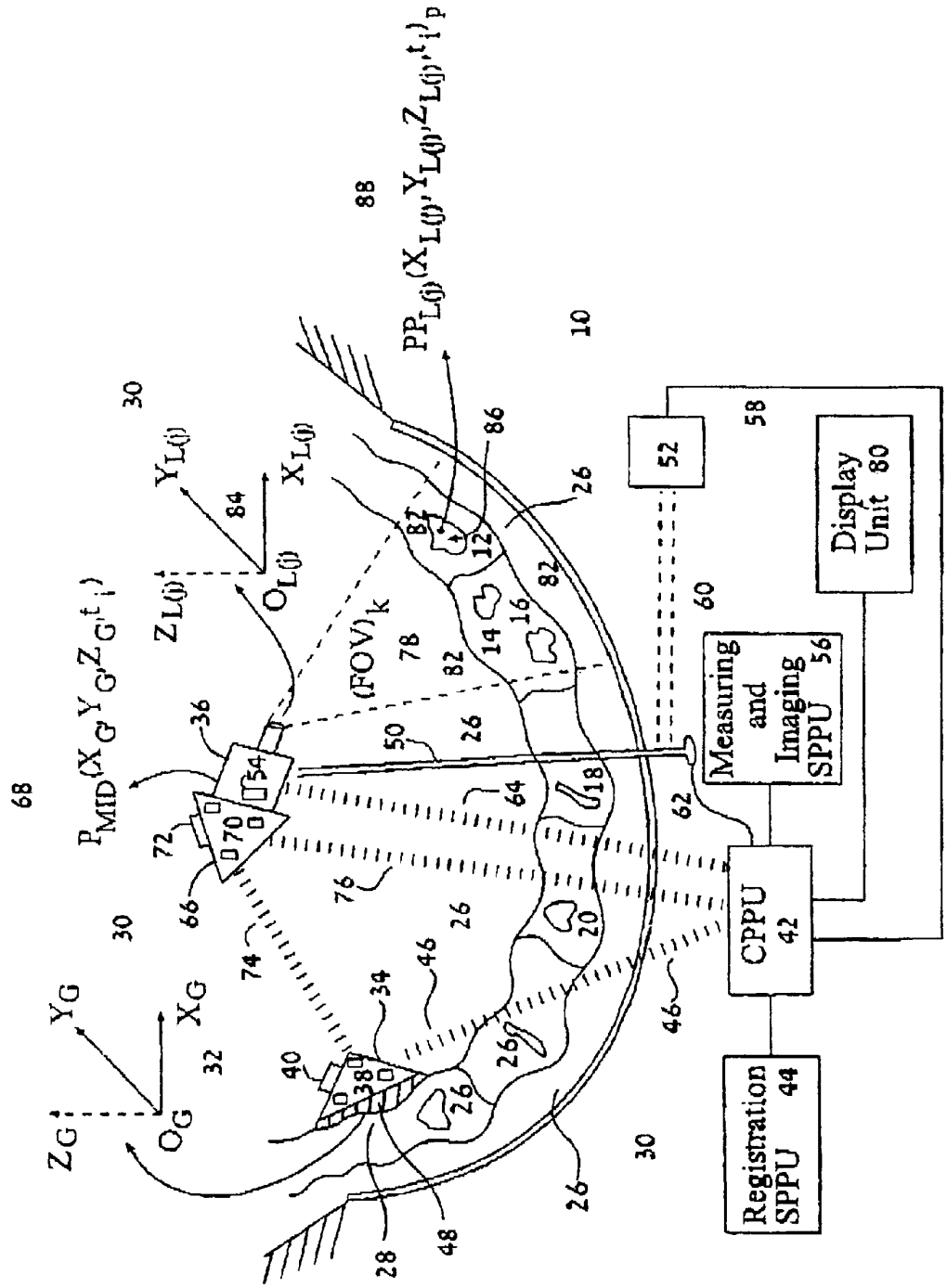

Measuring and Imaging SPPU 56
Display Unit 80
CPPU 42
Registration SPPU 44
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FIG.1

METHOD AND SYSTEM FOR REAL TIME INTRA-ORALLY ACQUIRING AND REGISTERING THREE-DIMENSIONAL MEASUREMENTS AND IMAGES OF INTRA-ORAL OBJECTS AND FEATURES

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to measuring, imaging, and mapping of intra-oral objects and features and, more particularly, to a method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, for primary application in the field of dentistry.

Commercial application of non-x-ray based imaging methods, devices, and systems in the field of dentistry, for automatically measuring, imaging, and mapping dental conditions of patients, is still significantly limited, even in view of the current rapid rate of developing and applying a wide variety of non-x-ray based imaging techniques in various other fields. The main objective, and benefit, of using automatic measuring and imaging techniques in dentistry, hereinafter also referred to as 'dental measuring/imaging', is to enable dental practitioners such as dentists, dental hygienists, and dental technicians to obtain highly accurate and precise realistic measurements, images, and spatial maps of intra-oral objects and features such as teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and prostheses of any kind, of dental patients, for the goal of improving procedures and processes, and decreasing costs, relating to examining, charting, diagnosing, and treating dental conditions of those patients.

Details of limitations and shortcomings associated with conventional non-imaging techniques currently used for examining, charting, diagnosing, and treating dental conditions of patients, in general, and for designing, manufacturing, fitting, and monitoring dental prostheses, in particular, are adequately described in dental literature and related prior art, for example, in U.S. Pat. No. 5,440,393, issued to Wenz, in PCT International Publication No. WO 98/52493, in U.S. Pat. No. 5,273,429, issued to Rekow et al., in U.S. Pat. No. 4,964,770, issued to Steinbichler et al., and in U.S. Pat. No. 5,857,853, issued to van Nifterick et al.

A well known example illustrating the potentially significant utility, effectiveness, and, procedural and economic impact of successfully applying automatic measuring and imaging techniques to dentistry involves examining, charting, diagnosing, and treating dental patients requiring dental prostheses such as crowns, bridges, dentures, or implants. More specifically, data and information obtained from measuring, imaging, and mapping intra-oral objects and features can be directly used for highly accurately and cost effectively designing, manufacturing, fitting, and monitoring dental prostheses, thereby replacing currently used inaccurate, labor, material, time, and cost intensive, non-imaging techniques. Automatic dental measuring and imaging techniques are also applicable for performing various types of restorative procedures, occlusal registration, and, orthodontic and tempero mandibular joint (TMJ) dysfunction therapies.

Different categories of mechanisms, such as electrical, electronic, electromechanical, electro-optical, electromagnetic, radar, magnetic, magneto-mechanical, magnetic resonance, acoustic, ultrasound, sonar, photo-acoustic, telemetry, hybrids, and combinations of these, used for automatic three-dimensional measurement, imaging, and

mapping of objects, features, and distances, are widely known and employed in various fields. The particular category of electro-optical mechanisms used in measuring and imaging techniques includes, for example, time/light in flight, laser scanning, moire, laser speckle pattern sectioning, interferometry, photogrammetry, laser tracking, and structured light or active triangulation. Specialized interferometric techniques of shearography, diffraction grating, digital wavefront reconstruction and wavelength scanning, and conoscopic holography have recently been developed as useful electro-optical measuring, imaging, and mapping techniques. Electro-optical techniques are reviewed by Chen, F., in "Overview of three-dimensional shape measurement using optical methods", Opt. Eng. 39(1) Jan., 10–22, 2000, and are further described in references therein. Several of these electro-optical techniques have been specifically applied for measuring, imaging, and mapping intra-oral objects and features. Magnetic resonance and ultrasound imaging techniques are well developed and especially applied in the medical field.

Basic in any measuring and imaging technique for accurately and precisely measuring, imaging, or mapping objects and features is the determination, sub-division, and usage of the source space and source resolution associated with the measurements and images. Measurements and images are defined in terms of global and local coordinates of the source space. Global space refers to a global coordinate space, encompassing one or more local coordinate spaces, and is at source resolution. Local space refers to a local coordinate space that is contained within global space that is also at source resolution. Accordingly, by definition, each local coordinate space and all coordinate points or positions contained therein are local with respect to the global coordinate space, whereby they can be transformed, mapped, or related to corresponding global coordinate space and global coordinate points or positions, respectively. This procedure is commonly known as registration of local coordinate space and associated local coordinate points or positions with respect to, or in terms of, global coordinate space and associated global coordinate points or positions, within source space. The registration procedure is performed by using one or more reference, fiducial, or registration, points or markers defined in the global coordinate space, which can also be associated with one or more local coordinate spaces within the global coordinate space.

Hereinafter, the terms 'measuring system', 'measuring device', 'imaging system', and 'imaging device' are general, and are applicable to any category, such as those listed above, of automatic three-dimensional shape measurement, imaging, and mapping of objects and features. With respect to measuring, imaging, and mapping objects and features, the position and orientation of a measuring and imaging device such as an electro-optical measuring and imaging probe, an electromagnetic measuring and imaging probe, an ultrasound measuring and imaging probe, or a magnetic resonance measuring and imaging probe, can be characterized, described, or defined in terms of source or global coordinate space. Furthermore, for each measuring and imaging device global position, each field of view of the measuring and imaging device can be associated with a corresponding local coordinate space, within the source or global coordinate space, where the positions, orientations, and shapes or configurations, of the objects and features in each field of view of the measuring and imaging device are definable in terms of that local coordinate space. Applying a registration procedure here involves transforming or mapping local measurement and image data and information of

the objects and features to global measurement and image data and information of the objects and features, using the position and orientation of the measuring and imaging device in global coordinate space as the transforming or mapping common link between global and local coordinate spaces.

Implementation of an automatic measuring and imaging technique usually includes measurement and image processing hardware and software, for automatically performing mathematical operations involved in registering local with global coordinate spaces during and/or after measurement and imaging, and for manipulating and editing measurements and images acquired in local and/or global coordinate spaces. Following these procedures, the graphical or digitized measurements and images are displayed on a display device by converting measurement and image definition from source space into device space, where device space refers to the characteristics of the device, for example, device units or pixels, by which measurements and images are displayed.

In a given automatic measuring and imaging technique, some form of one of the following three methods, object rotation method, measuring and imaging device transport method, and, fixed measuring and imaging system with multiple measuring and imaging devices method, is usually employed for the three-dimensional measuring and imaging of objects and features. In particular, in the measuring and imaging device transport method, registration of coordinate spaces, and, measurement and imaging are typically performed at a number of different fields of view of the measuring and imaging device, according to the desired extent of measuring and imaging the objects and features in the source space. Measurement and image data and information are transformed from local coordinate spaces into the global or source coordinate space using an appropriate registration procedure. Measurements and images are subsequently pieced or merged together, using an appropriate best fit algorithm, for forming composite measurements and images, or maps, of the objects and features of interest, followed by converting measurement and image, and/or map, definition from source space into device space for displaying and/or storing the measurements and images, and/or maps, of the objects and features.

Three-dimensional shape measurement, imaging, and mapping of objects and features, such as intra-oral objects and features, requires the positioning of at least one measuring and imaging device such as an electro-optical measuring and imaging probe, an electromagnetic measuring and imaging probe, an ultrasound measuring and imaging probe, or a magnetic resonance measuring and imaging probe, at different locations within source or global coordinate space, such as the oral cavity or mouth of a dental patient. Accordingly, each global location of the measuring and imaging device is associated with one or more fields of view, where each field of view is characterized or described by a corresponding local coordinate space, within the global coordinate space, and where the positions, orientations, and shapes or configurations, of objects and features of interest such as teeth, gum, intra-oral soft tissue, and dental fixtures or prostheses of any kind, are definable in terms of that local coordinate space.

In order to register point clouds or, measuring and imaging data associated with objects and features located in such local coordinate spaces, in terms of the global coordinate space, each measuring and imaging device coordinate system location and orientation must be accurately and precisely known or measured. Any error in measuring and/or

calculating the measuring and imaging device location and orientation causes propagation error in the registration procedure, thereby decreasing accuracy and precision of final output data and information, such as measurements and images, and/or maps, of the particular objects and features of interest.

Various methods are available for enabling the performing of the registration procedure between local and global coordinate spaces, where a particular method used is compatible with a particular measuring and imaging technique, such as those in the above list of categories of automatic three-dimensional shape measurement, imaging, and mapping of objects and features. Commonly used methods for performing the registration procedure are based on: (1) electromechanical location and orientation of the measuring and imaging device, whereby the measuring and imaging device is attached to, or are part of, a highly accurate and precise electromechanical system used for moving and fixing the positions of the measuring and imaging device throughout source or global coordinate space, (2) photogrammetry, also known as pattern recognition, of reference, fiducial, or registration, points or markers accurately located and fixed, and necessarily visible by the measuring and imaging device in the same field of view, or local coordinate space, of the particular objects and features being measured and imaged, (3) optical tracking of each measuring and imaging device location and/or orientation, whereby active or passive optical targets associated with local coordinate spaces defined within source or global coordinate space, are attached to, or part of, each measuring and imaging device, using an optical tracker system, and (4) hybrids of these methods.

Exemplary prior art electro-optical based methods, devices, and systems, each operating with some form of one of the above described registration procedures, for measuring, imaging and mapping intra-oral objects and features, with particular application to dentistry, are briefly summarized below.

In U.S. Pat. No. 4,935,635, issued to O'Harra, there is disclosed a three-dimensional measuring system particularly for dental and other space-limited uses, featuring a laser diode projecting a triangulating beam which scans the surface of intra-oral objects and features, such as a tooth, to be imaged and mapped. Preferably, in a given field of view, three teeth are scanned at a time, with resolution or accuracy of at least fifty microns. The registration procedure is based on the method of electromechanical location and orientation of a mostly extra-orally located imaging device including a probe, highly accurate axial stepping motors, a scanning laser beam, and photodetectors.

In U.S. Pat. No. 4,964,770, issued to Steinbichler et al., there is disclosed a process of making artificial teeth, featuring the use of interferometry, moire and laser scanning imaging methods. Three-dimensional shapes of the ground tooth and of the required artificial tooth are computed in accordance with an optic-geometric formula relating pixel parameters of intensity, background brightness, contrast, and angle. Description is provided for optically imaging only a single ground tooth and non-specific adjacent surfaces. The registration procedure is based on the method of electromechanical location and orientation of components of an extra-orally located imaging system including a light projector, diffraction grating, and a video camera.

In U.S. Pat. No. 5,372,502, issued to Massen et al., there is disclosed an optical probe and method for intra-oral three-dimensional surveying of teeth, including the use of a

mobile two-dimensional LCD matrix plate pattern projection unit, optic fibers projecting patterned light beams into the oral cavity, and a CCD matrix image sensor, operating in accordance with moire, phase-shift, triangulation, and photogrammetry techniques. Through a comparison between the undistorted pattern projected by the probe and the distorted pattern reflected from the specific area within the oral cavity, topographical information of the imaged teeth is obtained. A formal registration procedure relating local coordinate spaces of the projected and reflected patterns to source or global coordinate space of the oral cavity is not described in this disclosure, however, it is indicated that instead of using accurately controllable axial mechanical diffraction gratings, supposedly for enabling registration of local coordinate spaces, the surveying procedure is repeated a number of times, whereby accuracy of the imaging data and information is improved by iteration. Overall accuracy and precision of the method are directly dependent upon the extent of simultaneous non-movement of both the optical probe and of the patient during surveying each specific intra-oral region.

In U.S. Pat. No. 5,386,292, issued to Massen et al., there is disclosed a method for correcting imaging errors due to non-optimal reflection qualities of teeth, during three-dimensional optical measurement and imaging of teeth, featuring the use of a light pattern projector and an imaging device such as a CCD matrix image sensor, operating in accordance with moire, phase-shift, and triangulation techniques. Correction is based on determining the angle of incidence of the measuring rays on the surface of a tooth. The registration procedure is based on the method of electromechanical location and orientation of mostly extra-orally located imaging equipment.

In U.S. Pat. No. 5,413,481, issued to Goppel et al., there is disclosed a method and apparatus for manufacturing fitting members, such as for a dental prosthesis, featuring the use of a CCD matrix camera for photographing moire fringes resulting from repeatedly projecting an optical groove grating in a slightly offset manner onto a prepared tooth stump. Description is provided for optically imaging only a single tooth stump. The registration procedure is based on the method of electromechanical location and orientation of components of an essentially extra-orally located imaging system including a projector device, a grating, mirrors, and, stepping motors and springs for fine positional control of the grating.

In U.S. Pat. No. 5,440,393, issued to Wenz, there is disclosed a process and device for measuring the dimensions of a buccal cavity having upper and lower dentition, featuring the use of variable forms of a partly intra-oral optical radiation projection scanning device including light interference and deflection elements, and, an optical signal recording and digitizing system, operating in accordance with photogrammetry, triangulation, and holography techniques. Alternative registration procedures are used, including the method of electromechanical location and orientation of components of the scanning device, and photogrammetry. For photogrammetric registration, the position and orientation of the scanning device are determined relative to the dentition of the buccal cavity, by using an extra-orally located and fixed patient skull frame device supporting three lead balls functioning as reference, or registration, points accurately located and fixed, and necessarily visible by the scanning device, in the same field of view, or local coordinate space, of each image of the buccal cavity.

In U.S. Pat. No. 5,237,998, issued to Duret et al., there is disclosed a method for correlating three-dimensional images of dental arcades, for example, a tooth stump surrounded by two healthy teeth, by correlating intra-oral imaging data of a dental impression of the arcade in the occlusive position with that of the arcade without impression material, where three mutually spaced apart reference points are located and fixed in the immediate vicinity of the arcade. The registration procedure is based on the method of photogrammetry, whereby an intra-oral device featuring a clamp or bar is used for supporting three small spheres functioning as the three reference, or registration, points, accurately located and fixed, and necessarily visible by an imaging device, in the same field of view, or local coordinate space, of every image of the dental arcade.

In U.S. Pat. No. 5,857,853, issued to van Nifterick et al., there is disclosed a method and system for automatically manufacturing a prosthesis to be fixed to implants in the jawbone of a patient, including an intra-oral imaging technique featuring the use of at least one camera positioned at the opened mouth of the patient for three-dimensionally imaging each implant from at least two different oral positions. The registration procedure is based on the method of photogrammetry, whereby 100–150 micron diameter optical recognition points engraved into intra-oral inserts accurately located and fixed onto, and projecting above, each implant, function as the reference, or registration, points, necessarily visible by the camera, in the same field of view, or local coordinate space, of every image of an implant.

To date, the inventor is unaware of a registration procedure based on optical tracking, or based on any type of automatic tracking, featuring wired and/or wireless signal communication mechanisms, of a measuring and imaging device location and/or orientation for implementing a dental measuring and imaging technique.

It is apparent in view of the prior art, that current registration procedures used for implementing dental measuring and imaging techniques are typically based on either electromechanical location and orientation of the measuring and imaging device in source or global coordinate space relative to the intra-oral objects and features being measured or imaged in local coordinate spaces, or, photogrammetry or pattern recognition, of reference, fiducial, or registration, points or markers accurately located and fixed in source or global coordinate space, and necessarily visible by the measuring and imaging device in the same field of view, or local coordinate space, of the particular objects and features being measured or imaged. In general, each of these registration procedures particularly used in dental measuring and imaging has significant limitations, which may be a primary reason for the current relatively worldwide low volume application of non-x-ray based commercial dental measuring and imaging systems.

Electro-mechanical based registration procedures inherently involve the design, manufacture, real time hands-on operation, and maintenance of highly accurate, precise, complex, and expensive, electromechanical devices, mechanisms, components, and elements for enabling proper positional and orientational control of the measuring and imaging device relative to the objects and features of the oral cavity of the dental patient. Moreover, an operator must skillfully, and timely, during a patient visit, adjust the electro-mechanics for re-positioning the measuring and imaging device in order to change fields of view, clearly required for measuring and imaging a plurality, especially a panoramic or complete set, of intra-oral objects and features located throughout the oral cavity of the patient.

A particular limitation of employing electromechanical based registration procedures occurs each time the patient or

measuring and imaging device moves immediately prior to or during the measuring and imaging process, whereby, the operator must adjust the electro-mechanics for re-positioning the measuring and imaging device, in order to re-establish the global coordinates of the measuring and imaging device, consequently involving re-registration of local coordinates relative to the new global coordinates.

Photogrammetry or pattern recognition based registration procedures do not require the extent of complex and expensive electromechanical hardware and/or software, however, by definition, the reference, fiducial, or registration, points or markers accurately located and fixed, and necessarily visible by the measuring and imaging device, in the same field of view, or local coordinate space, of one particular set of intra-oral objects and features being measured and imaged, must skillfully, and timely, during a patient visit, be re-positioned in the same field of view of each other particular set of intra-oral objects and features being measured and imaged by an operator. Similar to electromechanical based registration procedures, the re-positioning procedure is clearly required for measuring and imaging a plurality, especially a panoramic or complete set, of intra-oral objects and features located throughout the oral cavity of the patient.

Another particular limitation of employing photogrammetry based registration procedures is that reference, fiducial, or registration, points or markers, need to be of proper color, dimensions and shapes or configurations in order to be properly located, fixed, and distinguishable in a variety of relatively small local coordinate spaces associated with the intra-oral objects and features. Moreover, different colors, sizes and shapes or configurations of the points or markers may need to be used for measuring and imaging the intra-oral objects and features of a single patient, according to the particular intra-oral geometric topography of the patient, and/or according to the extent of dental measuring and imaging needed by the patient.

Additional significant limitations of current dental measuring and imaging techniques in general, which are particularly relevant to the design, manufacture, and fitting, of dental fixtures or prostheses, relate to three-dimensional measuring and measuring and imaging of intra-oral objects and features having one or more undercuts and/or color and shape or structural gradients.

In the field of dentistry, an 'intra-oral undercut', or equivalently, an 'undercut', is properly defined in terms of the following description. If a vertical plane is brought into contact with a curved surface, where the curved surface includes smooth and rough portions, such as the surface of intra-oral objects and features including topological projections, the vertical plane will contact the surface at local maxima points of convexity. If such a curved surface is rotated, while remaining in contact with the vertical plane, an outline is traced corresponding to the maximum perimeter of the curved surface. The region of the curved surface, for example, the region of the surface of intra-oral objects and features, above the outline is referred to as the 'non-undercut' region, and the region below the outline is referred to as the 'undercut' region.

The extent of an intra-oral undercut region varies according to the tilt or angle of the particular intra-oral objects and features in relation to the vertical line. With respect to performing a restorative procedure on intra-oral objects and features, generally, one vertical approach is used for examining and imaging each field of view of the intra-oral objects and features, and subsequently, restoration of the intra-oral objects and features. Therefore, in actuality, as intra-oral objects and features are titled toward or away from each other, an undercut region is essentially always present. For intra-oral objects and features prepared for a restorative procedure, the main strategy is to eliminate undercut regions in restoration preparations by cutting or drilling the target intra-oral objects and features, and filling in undercuts with restorative material, for forming a common 'vertical view', also known as a common 'path of insertion'. In dental practice, however, it is not always possible to perform such ideal restorative preparations.

In dental practice, an undercut can also be referred to as the surface of intra-oral objects and features which, upon removal of set dental impression material from the vicinity of the intra-oral objects and features, causes distortion of the dental impression due to the shape and/or configuration of the undercut, and not due to physicochemical properties of the impression material. Specifically, teeth in normal or treated conditions are usually angled, worn, and/or broken, to varying degrees, causing the presence of undercuts. For example, teeth are typically intentionally drilled down and/or cut by a dental practitioner in order to remove diseased material, such as removal of caries from a tooth, and in preparation of a dental prosthesis.

Intra-oral objects and features, such as teeth, gum, soft tissue, dental fixtures and prostheses of any kind, in normal or treated conditions, are characterized by color and, shape or structural, gradients. Clearly, there exist measuring and imaging limitations, even when applying a dental measuring and imaging technique featuring the use of multiple measuring and imaging devices, caused by the presence of undercuts and, color and shape or structural gradients which need to be addressed for successfully implementing a given dental measuring and imaging technique, in order for information obtained from the measuring and imaging data to be useful to a dental practitioner.

Implementing dental measuring and imaging systems operating with electromechanical or photogrammetric based registration procedures requires working under the above described constrained and limiting conditions. In order to obtain and use accurate and precise panoramic intra-oral measurement and imaging data and information in basic and advanced dental applications, measurements and images from multiple fields of view need to be pieced or merged together, using an appropriate best fit algorithm, for forming composite measurements and images, or maps, of the intra-oral objects and features, usually followed by converting measurements and image, and/or map, definition from source space into device space for displaying and storing the measurements and images, and/or maps, of the intra-oral objects and features. Even for a dental measuring and imaging technique providing high resolution single field of view measurements and images of intra-oral objects and features, any error in measuring and/or calculating locations and/or orientations of the measuring and imaging device relative to the intra-oral objects and features, causes propagation error in the registration procedure, translating to propagation error in the measurement and image piecing or merging procedure, thereby decreasing accuracy, precision, and utility, of final output data and information needed by the dental practitioner.

There is thus a need for, and it would be highly advantageous to have a method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features. Moreover, there is a need for such a method and system which are generally applicable to different categories of techniques of automatic three-dimensional shape

measurement, imaging, and mapping of intra-oral objects and features, in the field of dentistry.

SUMMARY OF THE INVENTION

The present invention relates to a method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features.

According to the present invention, there is provided a method for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising the steps of: (a) establishing an intra-oral fixed global registration position inside the oral cavity of the dental patient, the intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, the global coordinate space is associated with a fixed global reference coordinate system, the global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity; (b) providing a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity; (c) selecting a field of view of the measuring and imaging device located at a global position in the global coordinate space of the oral cavity; (d) acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in the selected field of view of the measuring and imaging device, and, recording the global position of the measuring and imaging device relative to the intra-oral fixed global registration position, for forming at least one globally recorded three-dimensional measurement and image of the intra-oral objects and features located in the oral cavity; (e) repeating step (c) and step (d) for a plurality of said global positions and a plurality of the fields of view of the measuring and imaging device, for forming a plurality of the globally recorded three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient; and (f) registering local coordinate space pixel positions in each of the plurality of globally recorded three-dimensional measurements and images with corresponding global coordinate space pixel positions, for forming a plurality of the three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient which are registered relative to the same intra-oral fixed global registration position.

According to another aspect of the present invention, there is provided a system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, where the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising: (a) an intra-oral fixed global registration position inside the oral cavity of the dental patient, the intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, the global coordinate space is associated with a fixed global reference coordinate system, the global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity; (b) a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity, relative to the same intra-oral fixed global registration position; and (c) a mobile registration device for measuring and recording global positions and orientations of the measuring and imaging device, relative to the same intra-oral fixed global registration position.

According to further features in preferred embodiments of the invention described below, the intra-oral objects and features are selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside the oral cavity of the dental patient.

According to further features in preferred embodiments of the invention described below, data and information extractable from the measuring and imaging the intra-oral objects and features located in the oral cavity relative to the same intra-oral fixed global registration position are used in a dental procedure selected from the group consisting of charting an oral condition, diagnosing an oral condition, and treating an oral condition, of the dental patient.

The method and system of the present invention serve as significant improvements over those currently used in the field of dental measuring and imaging, by providing an effective and efficient method and system for acquiring and registering three-dimensional measurements and images of intra-oral objects and features located in multiple fields of view of a measuring and imaging device, which are all registered to the same intra-oral fixed global registration position. This results in eliminating, or at least minimizing, propagation errors relating to piecing and merging together three-dimensional measurement and imaging data and information, especially needed for obtaining highly accurate and precise panoramic measurements and images of intra-oral objects and features located throughout the oral cavity of the dental patient.

Implementation of the method and system of the present invention involves performing or completing selected tasks or steps manually, automatically, or a combination thereof Moreover, according to actual instrumentation and equipment of a particular embodiment, several selected steps of the present invention could be implemented by hardware or by software on any operating system of any firmware or a combination thereof. For example, as hardware, selected steps of the invention could be implemented as a chip or a circuit. As software, selected steps of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system.

BRIEF DESCRIPTION OF THE DRAWING

The invention is herein described, by way of example only, with reference to the accompanying drawing, wherein:

FIG. **1** is a schematic diagram illustrating exemplary preferred embodiments of the system for real time intra-orally registering and acquiring three-dimensional measurements and images of intra-oral objects and features, in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features. Hereinafter, meanings and usage of the terms source space or source coordinate space, global space or global coordinate space, and local space or local coordinate space correspond to commonly known and used meanings and usage of these terms in prior art teachings of measuring, imaging, and mapping. Hence, source space or source coordinate space encompasses both global space or global coordinate space, and, local spaces or local coordinate spaces. Global space or global coordinate space encompasses a plurality of local spaces or local coordinate spaces.

In the description of the present invention, source space or source coordinate space, and, global space or global coor-

dinate space, can both be associated with the same reference coordinate system, whereby the origin, axes, and coordinates of the reference coordinate system are the same for both the source space or source coordinate space and the global space or global coordinate space. For example, source space or source coordinate space, or, global space or global coordinate space can be equivalently used with reference to the space of the oral cavity of a dental patient. Moreover, positions of intra-oral objects and features, such as a part or entirety of any combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses of any kind, permanent or removable, located in a plurality of intra-oral local spaces or intra-oral local coordinate spaces in the oral cavity can be related to, or registered in terms of, source space or source coordinate space, or, global space or global coordinate space, with respect to the previously described reference coordinate system. For clarity and consistency, the terms global space or global coordinate space, and, intra-oral local space or intra-oral local coordinate space, are preferably used throughout the description of the present invention.

Different aspects of novelty of the present invention include, and are based on, the step of establishing an intra-oral fixed global registration position inside the oral cavity of a dental patient. Performing this step enables real time acquiring three-dimensional measurements and images of intra-oral objects and features located in multiple fields of view of a mobile measuring and imaging device moved around, positioned, and orientated at various locations in the oral cavity global space, and recording the various positions and orientations of the measuring and imaging device relative to the same intra-oral fixed global registration position, where the intra-oral fixed global registration position is not limited to being in any particular field of view of measured and imaged intra-oral objects and features.

More specifically, a significant aspect of the novelty here is that of enabling the real time registering of all local coordinate space pixel positions of the acquired and globally recorded three-dimensional measurements and images with global coordinate space pixel positions located in global coordinate space, for forming the three-dimensional measurements and images which are all registered with respect to the same intra-oral fixed global registration position in global coordinate space of the oral cavity of the dental patient. Regardless of the particular category or type of dental measuring and imaging technique applied, the prior art has no teaching of the establishment and use of the same intra-oral fixed global registration position located in global coordinate space inside the oral cavity of a dental patient, for the purpose of registering all local coordinate space pixel positions of all acquired three-dimensional measurements and images of intra-oral objects and features.

Clearly, these novel features lead to significant improvement in obtaining and using accurate and precise panoramic intra-oral measurement and imaging data and information in basic and advanced dental applications, whereby measurements and images from multiple fields of view are merged together for forming composite measurements and images, or maps, of the intra-oral objects and features, followed by converting measurement and image, and/or map, definition from source or global space into device space for displaying, storing, and further using the measurements and images, and/or maps, of the intra-oral objects and features.

It is to be understood that the invention is not limited in its application to the details of construction, arrangement, and composition of the components set forth in the following description, drawings, or examples. For example, the following description features different embodiments of a generalized method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, in order to illustrate implementation of the present invention. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

Steps, components, operation, and implementation of a method and system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, according to the present invention are better understood with reference to the following description and accompanying drawing.

FIG. **1** is a schematic diagram illustrating an exemplary preferred embodiment of the system **10** for real time intra-orally registering and acquiring three-dimensional measurements and images of intra-oral objects and features, such as **12**, **14**, **16**, **18**, **20**, **22**, and **24**, where the intra-oral objects and features, such as **12–24**, are located inside the oral cavity **26** of a dental patient (not shown). Typical intra-oral objects and features, such as **12–24**, are selected from the group consisting of a part or entirety of any combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses of any kind, permanent or removable, located inside oral cavity **26** of the dental patient.

In Step 1 of the method, there is real time establishing an intra-oral fixed global registration position inside the oral cavity of the dental patient. Accordingly, the intra-oral fixed global registration position, for example, **28**, is established in terms of global coordinate space **30** of oral cavity **26**, of the dental patient. Global coordinate space **30** is associated with a fixed global reference coordinate system, such as fixed global reference orthogonal coordinate system **32**, featuring fixed global coordinate system axes, X_G-axis, Y_G-axis, Z_G-axis, and fixed global coordinate system origin, O_G. In principle, any other curvilinear coordinate system, for example, a cylindrical, spherical, or hyperbolic, coordinate system, can be used for defining the fixed global reference coordinate system, associated with global coordinate space **30** of oral cavity **26**.

Intra-oral fixed global registration position **28**, global coordinate space **30**, and associated fixed global reference coordinate system **32** are established particularly for defining positions of fixed and/or movable objects, features, devices, instruments, and components, throughout oral cavity **26**. However, to accomplish the objectives of the present invention of real time intra-orally registering and acquiring three-dimensional measurements and images of intra-oral objects and features, they are generally applicable for defining positions of fixed and/or movable objects, features, devices, instruments, and components, outside of oral cavity **26**.

In sub-step (a), of Step 1, there is providing an intra-oral fixed global registration device **34**, used for measuring and determining distances from intra-oral fixed global registration position **28** to a measuring and imaging device, such as **36**, further described below. Preferably, physical space or volume occupied by intra-oral fixed global registration device **34** is substantially smaller than total physical space or volume of oral cavity **26** of the dental patient.

Intra-oral fixed global registration device **34** includes a mechanism for sensing or receiving registration signals and

responding to registration signals, where a registration signal is any signal relating to the process of registering intra-oral local coordinate space with global coordinate space, as further described below. Additionally, or alternatively, intra-oral fixed global registration device **34** includes a mechanism for transmitting registration signals. Optionally, intra-oral fixed global registration device **34** also includes a mechanism for locally processing sensed or received registration signals, and for locally programming responses to registration signals, and/or, for locally programming transmission of registration signals. For example, a programmed response to a sensed or received registration signal could be in the form of a programmed transmission registration signal. Registration signals can feature any type of analog or digital stimulus, response, and/or data suitable for enabling measuring and recording positions of a measuring and imaging device with respect to intra-oral fixed global registration position **28**.

Accordingly, intra-oral fixed global registration device **34** includes at least one, preferably a plurality, of components **38** selected from the group consisting of registration signal sensors, registration signal receivers, registration signal transmitters, and registration signal transceivers. Optionally, intra-oral fixed global registration device **34** also includes a local registration signal programmer and processor (RSPPU) **40**, for locally programming and processing registration signals. Intra-oral fixed global registration device **34** in general, and device components **38**, optional local registration signal processor and programmer **40**, and registration signals, in particular, are designed, configured, and operate according to a category of mechanisms used for measuring distances and recording positions of objects and features selected from the group consisting of electrical, electronic, electromechanical, electro-optical, electromagnetic, radar, magnetic, magneto-mechanical, magnetic resonance, acoustic, ultrasound, sonar, photo-acoustic, telemetry, hybrids, and combinations of these.

Furthermore, intra-oral fixed global registration device **34** in general, and device components **38**, optional local registration signal programmer and processor **40**, and registration signals, in particular, are designed, configured, and operate according to analog circuitry and/or digital circuitry, and according to a wireless communications mode and/or according to a wired communications mode.

In a preferred embodiment of system **10** featuring a wireless communications mode, intra-oral fixed global registration device **34** is in communication with a central programming and processing unit, for example, CPPU **42**, including a registration signal programming and processing unit, RSPPU **44**, via a wireless communication link **46**, for receiving centralized registration programming and processing data and information from CPPU **42**, and for sending local registration programming and processing data and information to CPPU **42**. Wireless communication link **46** is preferably, but not limited to, a form of an electromagnetic signal such as a microwave signal, or a sound wave signal.

In an alternative preferred embodiment of system **10** featuring a wired communications mode, intra-oral fixed global registration device **34** is in communication with central programming and processing unit, CPPU **42**, including registration signal programming and processing unit, RSPPU **44**, via a wired communication link **46**, for receiving centralized registration programming and processing data and information from CPPU **42**, and for sending local registration programming and processing data and information to CPPU **42**. Wired communication link **46** is preferably, but not limited to, a form of an electrical or electronic signal.

In sub-step (b), there is selecting and attaching a substrate for holding intra-oral fixed global registration device **34**. Alternatively, intra-oral fixed global registration device **34** features no substrate. In this case, there is continuing the method with sub-step (c), whereby intra-oral fixed global registration device **34** is positioned and fixed directly onto an intra-oral object and/or feature inside oral cavity **26** of the dental patient.

For performing sub-step (b), referring to FIG. **1**, a substrate **48** features any suitable single or multi-layered configuration or combination of a composition or material selected from the group consisting of biological components, chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components, which causes minimal interference with proper operation of intra-oral fixed global registration device **34**. For example, substrate **48** features a single component or any combination of an organic chemical such as a plastic, an acrylic, an adhesive or glue, and, an inorganic chemical such as a metallic component such as a screw, a pin, or a clamp, or, a silica based component such as a glass or a ceramic.

In sub-step (c), there is positioning and fixing intra-oral fixed global registration device **34** inside oral cavity **26** of the dental patient. This includes positioning and temporarily fixing intra-oral fixed global registration device **34**, either with or without a substrate, for example, substrate **48**, to any intra-oral object or feature inside oral cavity **26**. In particular, intra-oral fixed global registration device **34** is positioned and temporarily fixed onto any intra-oral object and/or feature, such as any intra-oral object and/or feature **12–24**, selected from the group consisting of a part or entirety of any combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses of any kind, permanent or removable, located inside oral cavity **26** of the dental patient.

Intra-oral fixed global registration device **34** is temporarily fixed to any intra-oral object and/or feature **12–24** by using any suitable single or multi-layered configuration or combination of a composition or material selected from the group consisting of biological components, chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components, which causes minimal interference with proper operation of intra-oral fixed global registration device **34**, and, which causes minimal adverse reaction or effect such as irritation, marking, or infection, in oral cavity **26** of the dental patient during the period of time required for the measuring and imaging procedure.

For example, intra-oral fixed global registration device **34** is temporarily fixed to any intra-oral object and/or feature **12–24** by using a single component or combination of an organic chemical such as a plastic, an acrylic, an adhesive or glue, and, an inorganic chemical such as a metallic component such as a screw, a pin, or a clamp, or, a silica based component such as a glass or a ceramic.

Intra-oral fixed global registration device **34** is temporarily fixed to any intra-oral object and/or feature **12–24** in such a way as to remain fixed and rigid with respect to that intra-oral object and/or feature **12–24** during movement or activity of any other object, feature, device, instrument, component, or, the entirety, of oral cavity **26** of the dental patient during the measuring and imaging procedure. Completion of this step enables proper establishment of the intra-oral fixed global registration position, for example, **34**,

in terms of global coordinate space **30** of oral cavity **26** of the dental patient, where global coordinate space **30** is associated with an intra-oral fixed global reference coordinate system, such as X-axis, Y-axis, Z-axis, intra-oral fixed global reference orthogonal coordinate system **32**.

In Step 2, there is providing a measuring and imaging device, for measuring and imaging intra-oral objects and features, and for locally programming and processing measurement and imaging data and information. In FIG. **1**, measuring and imaging device **36** includes, among the variety of standard components and mechanisms for enabling measuring, imaging, and mapping, intra-oral objects and features, (i) a position and orientation guide **50**, (ii) an optional position and orientation guide automatic controller **52**, and (iii) a local measuring and imaging programming and processing unit **54**.

Measuring and imaging device **36** is for acquiring three-dimensional measurements and images of the intra-oral objects and features, for example, intra-oral objects and features **12–24**, located in oral cavity **26** of the dental patient. Measuring and imaging device **36** is designed and configured for operating either inside or outside of oral cavity **26**, for acquiring measurements and images of intra-oral objects and features. For example, according to actual implementation of the present invention, measuring and imaging device **36** may need to be positioned outside of oral cavity **26** in order to effectively measure and image intra-oral objects and features **12–24**. Accordingly, measuring and imaging device **36** is not limited to functioning only inside oral cavity **26** of the dental patient.

Position and orientation guide **50** is for three-dimensional maneuvering or guiding, positioning, and orienting measuring and imaging device **36** throughout global coordinate space **30**, typically, but not limited to, inside oral cavity **26** of the dental patient.

In a first preferred embodiment of system **10**, position and orientation guide **50** is designed, configured, and operates for enabling manual maneuvering or guiding, positioning, and orienting of measuring and imaging device **36** by an operator, such as a dental practitioner. For example, position and orientation guide **50** is a handle or a rod, made of any suitable physicochemical composition or material selected from the group consisting of plastic, glass, and metal components, which causes minimal interference with proper operation of system **10**, in general, and of measuring and imaging device **36**, in particular, and, which preferably causes no adverse reaction or effect such as irritation, marking, or infection, of oral cavity **26** of the dental patient during the period of time required for the measuring and imaging procedure.

Moreover, in this first embodiment, position and orientation guide **50** features appropriate electromechanical means (not shown), and is in electronic communication with a central programming and processing unit, for example, CPPU **42**, including a measuring and imaging signal programming and processing unit, MISPPU **56**, via control/data links **58**, for receiving centralized measuring and imaging device position and orientation control data and information from CPPU **42**, and for sending local position and orientation data and information to CPPU **42**.

In a second preferred embodiment, position and orientation guide **50** is designed, configured, and operates for enabling automatic, such as robotic, three-dimensional maneuvering or guiding, positioning, and orienting of measuring and imaging device **36** by an operator, such as a dental practitioner. In this embodiment, position and orientation guide **50** features appropriate electromechanical means (not shown), including electromechanical control/data links **60**, for enabling automatic control and communication of position and orientation guide **50** by position and orientation guide automatic controller **52**. Moreover, in this second embodiment, position and orientation guide automatic controller **52** is in electronic communication with a central programming and processing unit, for example, CPPU **42**, including a measuring and imaging signal programming and processing unit, MISPPU **56**, via control/data links **62**, for receiving centralized measuring and imaging device position and orientation control data and information from CPPU **42**, and for sending local position and orientation data and information to CPPU **42**.

Local measuring and imaging programming and processing unit **54** is for locally programming the measuring and imaging of intra-oral objects and features **12–24** by locally controlling activation and operation of measuring and imaging device **36**, and is for locally processing measurement and image signals, data, and information relating to intra-oral objects and features **12–24**.

Measuring and imaging device **36**, in general, and above indicated components **50**, **52**, **54**, **58**, **60**, and **62**, in particular, of measuring and imaging device **36** are designed, configured, and operate according to a category of mechanisms used for automatic three-dimensional shape measurement, imaging, and mapping of objects and features selected from the group consisting of electrical, electronic, electromechanical, electro-optical, electromagnetic, radar, magnetic, magneto-mechanical, magnetic resonance, acoustic, ultrasound, sonar, photo-acoustic, telemetry, hybrids, and combinations of these.

For example, measuring and imaging device **36** operates in the particular category of electro-optical measuring and imaging techniques, according to a technique selected from the group consisting of time/light in flight, laser scanning, moire, laser speckle pattern sectioning, interferometry, photogrammetry, laser tracking, and, structured light or active triangulation. Moreover, measuring and imaging device **36** can also operate according to a specialized interferometric technique such as shearography, diffraction grating, digital wavefront reconstruction and wavelength scanning, or conoscopic holography.

Furthermore, measuring and imaging device **36** in general, device components **50–62**, and measuring and imaging signals, in particular, are designed, configured, and operate according to analog circuitry and/or digital circuitry, and according to a wireless communications mode and/or according to a wired communications mode.

In a preferred embodiment of system **10** featuring a wireless communications mode, measuring and imaging device **36** is in communication with a central programming and processing unit, for example, CPPU **42**, including a measuring and imaging signal programming and processing unit, MISPPU **56**, via a wireless communication link **64**, for receiving centralized measuring and imaging programming and processing data and information from CPPU **42**, and for sending local measuring and imaging programming and processing data and information to CPPU **42**. Wireless communication link **64** is preferably, but not limited to, a form of an electromagnetic signal such as a radio wave signal, a microwave signal, or a sound wave signal.

In an alternative preferred embodiment of system **10** featuring a wired communications mode, measuring and imaging device **36** is in electronic communication with a central programming and processing unit, for example,

CPPU **42**, including a measuring and imaging signal programming and processing unit, MISPPU **56**, via wired control/data links, for example, bundled along or through position and orientation guide **50** and control/data links **62**, for receiving centralized measuring and imaging programming and processing data and information from CPPU **42**, and for sending local measuring and imaging programming and processing data and information to CPPU **42**. The wired communication link is preferably, but not limited to, a form of an electrical or electronic signal.

In Step 3, there is providing a mobile registration device, for enabling measuring and recording global positions and orientations of the measuring and imaging device, **36**, relative to the intra-oral fixed global registration position, **28**.

In FIG. **1**, exemplary mobile registration device **66** is used, in part, for measuring and recording global positions and orientations of measuring and imaging device **36** in global coordinate space **30** of oral cavity **26** of the dental patient, relative to intra-oral fixed global registration position **28**, where global coordinate space **30** is associated with fixed global reference orthogonal coordinate system **32**, featuring global coordinate system axes, X_G-axis, Y_G-axis, Z_G-axis, and global coordinate system origin, O_G. Relative to oral cavity **26**, any global position or orientation of measuring and imaging device **36**, for example, a j^{th} global position of measuring and imaging device, P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**, is describable in terms of global coordinates X_G, Y_G, Z_G, and time, t_i, where t_i corresponds to an i^{th} real time value during the performing of the measuring and imaging procedure using system **10**.

Mobile registration device **66**, in general, and below described components of mobile registration device **66**, in particular, are designed, configured, and operate as part of, and/or attached to, and/or separate from, measuring and imaging device **36**. As shown in FIG. **1**, mobile registration device **66** is preferably attached to measuring and imaging device **36**. More preferably, mobile registration device **66** is firmly and rigidly attached to measuring and imaging device **36**, in order to attain high accuracy and precision during the process of measuring and recording global positions, P_{MID} $(X_G, Y_G, Z_G, t_i)_j$, of measuring and imaging device **36** in global coordinate space **30**, relative to intra-oral fixed global registration position **28**.

As indicated above in Step 2, global positions of measuring and imaging device, P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**, are typically, but not limited to, intra-oral locations within oral cavity **26** of the dental patient. Accordingly, in the preferred embodiment where mobile registration device **66** is firmly and rigidly attached to measuring and imaging device **36**, mobile registration device **66** is not limited to functioning only inside oral cavity **26** of the dental patient. Similar to measuring and imaging device **36**, mobile registration device **66** is designed and configured for operating either inside or outside of oral cavity **26**.

As shown in FIG. **1**, according to the preferred embodiment of system **10**, where mobile registration device **66** is firmly attached to measuring and imaging device **36**, relative to oral cavity **26**, any global position of mobile registration device **66** within global coordinate space **30** is automatically associated with a corresponding global position of measuring and imaging device **36**, for example, j^{th} global position of measuring and imaging device, P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**. This association of global positions and orientations in global coordinate space **30** between mobile registration device **66** and corresponding global positions of measuring and imaging device **36** enables performing a principle novel step, Step 7 below, of registering or transforming pixel positions of three-dimensional measurements and images initially defined in local coordinate space, relative to a single intra-oral fixed global registration position **28** defined in global coordinate space **30**, for forming registered measurements and images of any part or entirety of intra-oral objects and features located in oral cavity **26** of the dental patient.

Mobile registration device **66** includes a mechanism for sensing or receiving registration signals and responding to registration signals. Additionally, or alternatively, mobile registration device **66** includes a mechanism for transmitting registration signals. Optionally, mobile registration device **66** also includes a mechanism for locally processing sensed or received registration signals, and for locally programming responses to registration signals, and/or, for locally programming transmission of registration signals. For example, a programmed response to a sensed or received registration signal could be in the form of a programmed transmission registration signal. Registration signals can feature any type of analog or digital stimulus, response, and/or data suitable for enabling recording of positions of a measuring and imaging device with respect to intra-oral fixed global registration position **28**.

Accordingly, mobile registration device **66** includes at least one, preferably a plurality, of components **70** selected from the group consisting of registration signal sensors, registration signal receivers, registration signal transmitters, and registration signal transceivers. Optionally, mobile registration device **66** also includes a local registration signal processor and programmer **72**. Mobile registration device **66** in general, and, device components **70**, optional local registration signal processor **72**, and registration signals, in particular, are designed, configured, and operate according to a category of mechanisms used for measuring distances and registering positions of objects and features selected from the group consisting of electrical, electronic, electromechanical, electro-optical, electromagnetic, radar, magnetic, magneto-mechanical, magnetic resonance, acoustic, ultrasound, sonar, photo-acoustic, telemetry, hybrids, and combinations of these.

Furthermore, mobile registration device **66** in general, and, device components **70**, optional local registration signal processor and programmer **72**, and registration signals, in particular, are designed, configured, and operate according to analog circuitry and/or digital circuitry, and according to a wireless communications mode and/or according to a wired communications mode.

Referring to FIG. **1**, in a preferred embodiment of system **10** featuring a wireless communications mode, mobile registration device **66** is in communication with intra-oral fixed global registration position **28**, by communicating with intra-oral fixed global registration device **34** via a wireless communication link **74**, for receiving registration signals from intra-oral fixed global registration device **34**, and/or for sending registration signals to intra-oral fixed global registration device **34**. Wireless communication link **74** is preferably, but not limited to, a form of an electromagnetic signal such as a radio wave signal, a microwave signal, or a sound wave signal.

In an alternative preferred embodiment of system **10** featuring a wired communications mode, mobile registration device **66** is in communication with intra-oral fixed global registration position **28**, by communicating with intra-oral fixed global registration device **34** via a wired communication link **74**, for receiving registration signals from intra-oral fixed global registration device **34**, and/or for sending reg-

istration signals to intra-oral fixed global registration device **34**. Wired communication link **74** is preferably, but not limited to, a form of an electrical or electronic signal.

In a preferred embodiment of system **10** featuring a wireless communications mode, mobile registration device **66** is in communication with a central programming and processing unit, for example, CPPU **42**, including a registration signal programming and processing unit, RSPPU **44**, via a wireless communication link **76**, for receiving centralized registration processing and programming data and information from CPPU **42**, and for sending local registration programming and processing data and information to CPPU **42**. Wireless communication link **76** is preferably, but not limited to, a form of an electromagnetic signal such as a radio wave signal, a microwave signal, or a sound wave signal.

In an alternative preferred embodiment of system **10** featuring a wired communications mode, mobile registration device **66** is in communication with a central programming and processing unit, for example, CPPU **42**, including a registration signal programming and processing unit, RSPPU **44**, via a wired communication link **76**, for receiving centralized registration processing and programming data and information from CPPU **42**, and for sending local registration programming and processing data and information to CPPU **42**. Wired communication link **76** is preferably, but not limited to, a form of an electrical or electronic signal.

In Step 4, there is selecting a field of view of the measuring and imaging device located at a global position in global coordinate space. Referring to FIG. **1**, there is selecting a particular field of view, for example, k^{th} field of view, $(FOV)_k$ **78**, of measuring and imaging device **36** located at a particular global position, for example, j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**, in global coordinate space **30** of oral cavity **26** of the dental patient. A field of view of measuring and imaging device **36** is selected from the group consisting of fields of view whereby intra-oral fixed global registration position **28** is located outside the field of view, and fields of view whereby intra-oral fixed global registration position **28** is located inside the field of view.

Specifically, as described above with reference to FIG. **1**, intra-oral fixed global registration position **28** is defined by a particular fixed location within global coordinate space **30** of oral cavity **26**, wherein preferably, physical space or volume occupied by intra-oral fixed global registration device **34** is substantially smaller than total physical space or volume of oral cavity **26** of the dental patient. Accordingly, during operation of system **10**, intra-oral fixed global registration position **28** is typically located outside any selected field of view, such as $(FOV)_k$ **78**, of measuring and imaging device **36**.

For example, in FIG. **1**, during real time measuring and imaging intra-oral objects and features **12**, **14**, and **16**, located in k^{th} field of view, $(FOV)_k$ **78**, of measuring and imaging device **36**, intra-oral fixed global registration position **28** is located outside k^{th} field of view, $(FOV)_k$ **78**. In contrast, however, during real time measuring and imaging intra-oral objects and features such as **22** and **24**, located in a different (not referenced) k^{th} field of view, $(FOV)_k$, of measuring and imaging device **36** located at a different (not referenced) j^{th} global position, P_{MID} $(X_G, Y_A, Z_G, t_i)_j$, in global coordinate space **30** of oral cavity **26**, for example, in the immediate vicinity or behind intra-oral fixed global registration position **28**, intra-oral fixed global registration position **28** may be located inside this k^{th} field of view, $(FOV)_k$, of measuring and imaging device **36**.

Each field of view, such as exemplary k^{th} field of view, $(FOV)_k$ **78**, of measuring and imaging device **36**, features any number of intra-oral objects and features, such as **12**, **14**, and **16**, selected from the group consisting of a part or entirety of any combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses of any kind, permanent or removable, located inside oral cavity **26** of the dental patient.

Step 4 is manually or automatically performed by an operator (not shown) of system **10**. In particular, in a manual mode of operation, an operator manually holds and moves position and orientation guide **50** for maneuvering measuring and imaging device **36** throughout oral cavity **26** until selecting a desired or target field of view, such as $(FOV)_k$ **78** of intra-oral objects and features such as **12**, **14**, and **16**. In an automatic mode of operation, an operator provides commands to central programming and processing unit, CPPU **42**, which communicates with position and orientation guide automatic controller **52** via control/data links **58**, for communicating with and automatically controlling position and orientation guide **50** via electromechanical control/data links **60**, which in turn communicates with and enables automatic control of positioning and orientation of measuring and imaging device **36**. Preferably, during manually or automatically selecting a field of view of measuring and imaging device **36**, a display device, for example, as part of a display unit **80**, is used for real time displaying measurements, images, data and information relating to and featured in each k^{th} field of view, such as $(FOV)_k$ **78**, of measuring and imaging device **36** to the system operator.

In Step 5, there is acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in the selected field of view of the measuring and imaging device, and recording the global position of the measuring and imaging device relative to the intra-oral fixed global registration position, for forming at least one globally recorded three-dimensional measurement and image of the intra-oral objects and features located in the oral cavity of the dental patient.

In sub-step (a) of Step 5, referring to FIG. **1**, there is acquiring at least one three-dimensional measurement and image of intra-oral objects and features **12**, **14**, and **16** located in exemplary k^{th} field of view, $(FOV)_k$ **78**, of measuring and imaging device **36**, by activating and operating measuring and imaging device **36**, located at a particular global position, for example, j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**, in global coordinate space **30** of oral cavity **26** of the dental patient. This involves central programming and processing unit **42** communicating with local measuring and imaging programming and processing unit **54**, preferably, but not limited to, via wireless communication link **64**. Following acquiring the at least one three-dimensional measurement and image of intra-oral objects and features **12**, **14**, and **16**, this step further includes storing the at least one three-dimensional measurement and image by central processing and programming unit **42**, for example, by operation of measuring and imaging signal processing and programming unit, MISPPU **56**.

In sub-step (b), of Step 5, there is recording j^{th} global position P_{MID} $(X_G, Y_G$ I $Z_G, t_i)_j$ **68** of measuring and imaging device **36** relative to intra-oral fixed global registration position **28** in global coordinate space **30** of oral cavity **26** of the dental patient. This involves mobile registration device **66**, preferably firmly and rigidly attached to measuring and imaging device **36** and associated with j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68** of measuring and imaging device **36**, communicating with intra-oral fixed

global registration device **34**, preferably, but not limited to, via wireless communication link **74**. Following recording j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68** of measuring and imaging device **36** relative to intra-oral fixed global registration position **28** in global coordinate space **30**, this step further includes storing the globally recorded position by central processing and programming unit **42**, for example, by operation of registration signal processing and programming unit, RSPPU **44**.

Sub-steps (a) and (b) of Step 5 are performed synchronously or asynchronously. In particular, sub-step (b) of recording and storing j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68** of measuring and imaging device **36** relative to intra-oral fixed global registration position **28** in global coordinate space **30** is performed at a real time selected from the group consisting of before, simultaneous to, and after, sub-step (a) of acquiring and storing at least one three-dimensional measurement and image of intra-oral objects and features **12**, **14**, and **16** located in k^{th} field of view $(FOV)_k$ **78** of measuring and imaging device **36**. This feature provides operational flexibility for implementing the method and system of the present invention.

In Step 6, there is repeating Steps 4 and 5 for a plurality of global positions and a plurality of fields of view of the measuring and imaging device, for forming a plurality of globally recorded three-dimensional measurements and images of a variety of intra-oral objects and features located throughout the oral cavity of the dental patient.

Referring to FIG. **1**, there is repeating Steps 4 and 5 for a plurality of global positions P_{MID} $(X_G, Y_G, Z_G, t_i)_j$, of measuring and imaging device **36**, for a pre-determined number of J positions, and for a plurality of fields of view, $(FOV)_k$, of measuring and imaging device **36**, for a pre-determined number of K fields of view. This step results in forming a plurality of globally recorded three-dimensional measurements and images of a variety of intra-oral objects and features located throughout oral cavity **26** of the dental patient, which are recorded relative to the same intra-oral fixed global registration position **28**.

In Step 7, there is registering local coordinate space pixel positions in each of the plurality of globally recorded three-dimensional measurements and images of the intra-oral objects and features of the oral cavity, relative to the intra-oral fixed global registration position, for forming a plurality of sets of global coordinate space pixel positions, which are registered relative to the same intra-oral fixed global registration point in the oral cavity of the dental patient.

In sub-step (a), of Step 7, there is defining an intra-oral local coordinate space, associated with an intra-oral local reference coordinate system, for each global position of the measuring and imaging device, whereat are globally recorded the plurality of three-dimensional measurements and images of the intra-oral objects and features. In FIG. **1**, for example, there is defining intra-oral local coordinate space **82**, associated with intra-oral local reference coordinate system **84**, featuring local orthogonal reference coordinate system axes, $X_{L(j)}$-axis, $Y_{L(j)}$-axis, $Z_{L(j)}$-axis, and local reference coordinate system origin, $O_{L(j)}$, for each j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68** of measuring and imaging device **36** in global coordinate space **30**, whereat is recorded the three-dimensional measurements and images of the intra-oral objects and features, as described in Step 6. In principle, any other curvilinear coordinate system, for example, a cylindrical, spherical, or hyperbolic, coordinate system, can be used for defining intra-oral local reference coordinate system **84**, associated with intra-oral local coordinate space **82** of oral cavity **26**.

Sub-step (a) provides part of the basis for establishing the necessary spatial and mathematical relationships between local coordinate space pixel positions in a plurality of intra-oral local coordinate spaces, such as **82**, and global coordinate space pixel positions in global coordinate space **30**, by using each j^{th} global position, P_{MID} $(X_G, Y_G, Z_G, t_i)_j$, such as **68**, of measuring and imaging device **36**, as the common link between global coordinate space **30** and the plurality of local coordinate spaces therein, needed for registering or transforming local coordinate space pixel positions to global coordinate space **30**.

In sub-step (b), of Step 7, there is assigning intra-oral local space coordinates to each intra-oral local coordinate space pixel position, for each of the plurality of globally recorded three-dimensional measurements and images of the intra-oral objects and features. In FIG. **1**, for example, there is assigning intra-oral local space orthogonal coordinates, $X_{L(j)}$, $Y_{L(j)}$, and $Z_{L(j)}$, and, time, t_i, to each pixel position, for example, p^{th} pixel position **86**, located in intra-oral local coordinate space **82**, for each of the previously globally recorded three-dimensional measurements and images of the intra-oral objects and features appearing in one or more fields of view, $(FOV)_k$, for example, k^{th} field of view $(FOV)_k$ **78**, for measuring and imaging device **36** located at j^{th} global position P_{MID} $(X_G, Y_G, Z_G, t_i)_j$ **68**. Accordingly, each assigned p^{th} pixel position, $(PP_{L(j)})$, is written in terms of intra-oral local space coordinates and time, thus, $PP_{L(j)}(X_{L(j)}, Y_{L(j)}, Z_{L(j)}, t_i)_p$ **88**, with reference to the global coordinates via the measuring and imaging device position index, (j). This step further includes storing each assigned local coordinate space pixel position by central programming and processing unit **42**.

In sub-step (c), of Step 7, there is transforming the intra-oral local space coordinates of each intra-oral local coordinate space pixel position, in each of the plurality of globally recorded three-dimensional measurements and images of the intra-oral objects and features, to the corresponding or proportionately equivalent global space coordinates, for forming a plurality of sets of global coordinate space pixel positions in global coordinate space which are registered relative to the same intra-oral fixed global registration point.

Referring to FIG. **1**, for example, this step involves applying any standard mathematical or algorithmic coordinate space registration technique known in the art, for example, involving matrix transformations, for transforming each local coordinate space pixel position, such as p^{th} pixel position, $PP_{L(j)}(X_{L(j)}, Y_{L(j)}, Z_{L(j)}, t_i)_p$ **88**, in each of the intra-oral local coordinate spaces, for example, intra-oral local coordinate space **82**, to a corresponding or proportionally equivalent global coordinate space pixel position in global coordinate space **30** of oral cavity **26** of the patient. This is performed for each of the plurality of globally recorded three-dimensional measurements and images of the intra-oral objects and features throughout oral cavity **26** of the dental patient.

This step leads to forming a plurality of sets of global coordinate space pixel positions registered in global coordinate space, which can then be associated with a plurality of three-dimensional measurements and images of the intra-oral objects and features located throughout oral cavity **26** of the dental patient, which are registered relative to same intra-oral fixed global registration point **28** in oral cavity **26** of the dental patient. This step further includes storing the

plurality of sets of registered global coordinate space pixel positions by central processing and programming unit **42**.

In Step 8, there is using the plurality of sets of registered global coordinate space pixel positions in global coordinate space, which can be associated with a plurality of three-dimensional measurements and images of the intra-oral objects and features located throughout oral cavity **26** of the dental patient, for performing a dental procedure on the dental patient.

Data and information extractable from the sets of registered global coordinate space pixel positions, corresponding to the plurality of globally recorded three-dimensional measurements and images of the intra-oral objects and features located throughout oral cavity **26** of the dental patient, are used in a dental procedure selected from the group consisting of charting an oral condition, diagnosing an oral condition, and treating an oral condition, of the dental patient. Furthermore, the globally recorded and registered three-dimensional measurement and imaging data and information may be used for a type of dental procedure selected from the group consisting of general dental maintenance, dental mapping, dental surgery, dental restoration, orthodontics, periodontics, occlusal registration, and tempero mandibular joint (TMJ) dysfunction therapies.

In particular, the present invention is applicable to dental restoration procedures selected from the group consisting of dental prostheses, such as crowns, bridges, dentures, and/or implants. Moreover, any of the above listed dental procedures may involve any number of intra-oral objects and features selected from the group consisting of a part or entirety of any combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses of any kind, permanent or removable, located inside oral cavity **26** of the dental patient.

For any of the above listed dental procedures involving display of the globally recorded and registered three-dimensional measurement and imaging data and information, Step 8 further includes converting at least one of the globally recorded and registered three-dimensional measurements and images from global space **30** into display device space (not shown), for forming at least one display device measurement and image defined and configured with respect to display device space. The display device measurement and image is subsequently displayed on a display device, for example, as part of display unit **80**, as shown in FIG. **1**.

An important and novel aspect of the method and system of the present invention is that the intra-oral fixed global registration position is not limited to being inside each field of view of the measuring and imaging device during measuring and imaging intra-oral objects and features, and/or during recording positions and orientations of the measuring and imaging device relative to the intra-oral fixed global registration position. As described above with reference to FIG. **1**, the intra-oral fixed global registration position, **28**, is defined by a particular fixed location within global coordinate space of the oral cavity of he dental patient, whereby during implementation of the present invention, the intra-oral fixed global registration position is typically located outside fields of view of the measuring and imaging device.

An important consequence of this aspect of the present invention, is that of enabling real time, continuously or discontinuously, acquiring and registering three-dimensional measurements and images of intra-oral objects and features located in multiple fields of view of a mobile measuring and imaging device moved around, positioned, and orientated at various locations throughout global coordinate space of an oral cavity of a dental patient, which are all registered to the same intra-oral fixed global registration position. This results in eliminating, or at least minimizing, propagation errors relating to piecing and merging together three-dimensional measurement and imaging data and information, especially needed for obtaining highly accurate and precise panoramic measurements and images of intra-oral objects and features located throughout the oral cavity of the dental patient.

Regardless of the particular category or type of dental measuring and imaging technique applied, the prior art has no teaching of the establishment and use of a single intra-oral fixed global registration position inside the oral cavity of a dental patient, for the purpose of registering all local coordinate space pixel positions of all the acquired globally recorded three-dimensional measurements and images of intra-oral objects and features to the same intra-oral fixed global registration position. Moreover, the method and system of the present invention are generally applicable to a diversity of techniques of three-dimensional measuring and imaging intra-oral objects and features of dental patients.

While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

What is claimed is:

1. A method for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising the steps of:

(a) establishing an intra-oral fixed global registration position inside the oral cavity of the dental patient, said intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, said global coordinate space is associated with a fixed global reference coordinate system, said global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity;

(b) providing a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity;

(c) selecting a field of view of said measuring and imaging device located at a global position in said global coordinate space of the oral cavity;

(d) acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in said selected field of view of said measuring and imaging device, and, recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position, for forming at least one globally recorded three-dimensional measurement and image of the intra-oral objects and features located in the oral cavity;

(e) repeating step (c) and step (d) for a plurality of said global positions and a plurality of said fields of view of said measuring and imaging device, for forming a plurality of said globally recorded three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient; and

(f) registering local coordinate space pixel positions in each of said plurality of globally recorded three-

dimensional measurements and images with corresponding global coordinate space pixel positions, for forming a plurality of the three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient which are registered relative to same said intra-oral fixed global registration position.

2. The method of claim **1**, wherein the intra-oral objects and features are selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside the oral cavity of the dental patient.

3. The method of claim **1**, wherein said global coordinate space features fixed and movable objects, features, devices, instruments, and components, at a location selected from the group consisting of inside the oral cavity and outside the oral cavity.

4. The method of claim **1**, wherein said fixed global reference coordinate system is a curvilinear coordinate system for enabling defining positions in said global coordinate space.

5. The method of claim **1**, wherein each of said plurality of intra-oral local coordinate spaces is associated with an intra-oral local reference coordinate system, said intra-oral local reference coordinate system is a curvilinear coordinate system for enabling defining positions in said intra-oral local coordinate space.

6. The method of claim **1**, wherein step (a) of establishing an intra-oral fixed global registration position inside the oral cavity of the dental patient, further comprises the steps of:

(i) providing an intra-oral fixed global registration device for measuring and determining distances of said measuring and imaging device to said intra-oral fixed global registration position;

(ii) optionally selecting and attaching a substrate for holding said intra-oral fixed global registration device; and

(iii) positioning and fixing said intra-oral fixed global registration device inside the oral cavity of the dental patient.

7. The method of claim **6**, wherein said intra-oral fixed global registration device includes a mechanism selected from the group consisting of sensing or receiving registration signals and responding to registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

8. The method of claim **6**, wherein said intra-oral fixed global registration device includes a mechanism for transmitting registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

9. The method of claim **6**, wherein said intra-oral fixed global registration device includes a mechanism for locally processing registration signals and for locally programming registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

10. The method of claim **6**, wherein said intra-oral fixed global registration device is designed, configured, and operates according to a category of mechanisms used for measuring distances and recording positions of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms, radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

11. The method of claim **6**, wherein said intra-oral fixed global registration device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

12. The method of claim **6**, wherein said substrate is selected from the group consisting of a single layered configuration and a multi-layered configuration, said configuration features a material composition selected from the group consisting of biological components, chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components.

13. The method of claim **6**, wherein said intra-oral fixed global registration device is positioned and fixed inside the oral cavity of the dental patient in a form selected from the group consisting of with said substrate and without said substrate.

14. The method of claim **6**, wherein said intra-oral fixed global registration device is positioned and fixed on an intra-oral object and feature selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside the oral cavity of the dental patient.

15. The method of claim **6**, wherein said intra-oral fixed global registration device is positioned and fixed inside the oral cavity of the dental patient in a configuration selected from the group consisting of a single layered configuration and a multi-layered configuration, said configuration features a material composition selected from the group consisting of biological components , chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components.

16. The method of claim **1**, wherein said measuring and imaging device is designed and configured for operating at a location selected from the group consisting of inside the oral cavity and outside the oral cavity.

17. The method of claim **1**, wherein said measuring and imaging device includes:

(i) standard components and mechanisms for said measuring and imaging the intra-oral objects and features located in the oral cavity;

(ii) a position and orientation guide for three-dimensional maneuvering, guiding, positioning, and orienting said measuring and imaging device throughout said global coordinate space selected from the group consisting of inside the oral cavity and outside the oral cavity, of the dental patient;

(iii) an optional position and orientation guide automatic controller for automatically controlling and communicating with said position and orientation guide; and

(iv) a local measuring and imaging programming and processing unit for locally programming said measuring and imaging of the intra-oral objects and features by locally controlling activation and operation of said measuring and imaging device, and for locally processing measurement and image signals, data, and information relating to the intra-oral objects and features.

18. The method of claim 1, wherein said measuring and imaging device is designed, configured, and operates according to a category of mechanisms used for three-dimensionally measuring and imaging of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms, radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

19. The method of claim 1, wherein said measuring and imaging device is designed, configured, and operates according to a category of electro-optical measuring and imaging techniques selected from the group consisting of time/light in flight, laser scanning, moire, laser speckle pattern sectioning, interferometry, photogrammetry, laser tracking, and, structured light or active triangulation.

20. The method of claim 1, wherein said measuring and imaging device is designed, configured, and operates according to a category of electro-optical measuring and imaging techniques selected from the group consisting of shearography, diffraction grating, digital wavefront reconstruction and wavelength scanning, and conoscopic holography.

21. The method of claim 1, wherein said measuring and imaging device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

22. The method of claim 1, wherein said field of view of said measuring and imaging device is selected from the group consisting of fields of view whereby said intra-oral fixed global registration position is located outside said field of view, and fields of view whereby said intra-oral fixed global registration position is located inside said field of view.

23. The method of claim 1, wherein said field of view of said measuring and imaging device includes intra-oral objects and features selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside oral cavity of the dental patient.

24. The method of claim 1, wherein the step of selecting a field of view of said measuring and imaging device located at a global position in said global coordinate space of the oral cavity is performed in a mode selected from the group consisting of manually selecting said field of view and automatically selecting said field of view.

25. The method of claim 1, wherein, in the step of acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in said selected field of view of said measuring and imaging device, and, recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position, said recording said global position of said measuring and imaging device is performed in a mode selected from the group consisting of synchronously and asynchronously with respect to said acquiring said at least one three-dimensional measurement and image.

26. The method of claim 1, wherein the step of recording said global position of said measuring and imaging device relative to said intra-oral fixed global registration position farther comprises the steps of:

(i) providing a mobile registration device for said measuring and recording said global positions and orientations of said measuring and imaging device relative to said intra-oral fixed global registration position;

(ii) associating said global position of said measuring and imaging device with said mobile registration device; and

(iii) effecting communication between said mobile registration device and said intra-oral fixed global registration device located at said intra-oral fixed global registration position, said communication features a registration signal with data and information indicating said global position of said measuring and imaging device.

27. The method of claim 26, wherein said mobile registration device includes a mechanism selected from the group consisting of sensing or receiving said registration signals and responding to said registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

28. The method of claim 26, wherein said mobile registration device includes a mechanism for transmitting registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

29. The method of claim 26, wherein said mobile registration device includes a mechanism for locally processing said registration signals and for locally programming said registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

30. The method of claim 26, wherein said mobile registration device is designed, configured, and operates according to a category of mechanisms used for measuring distances and recording positions of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms, radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

31. The method of claim 26, wherein said mobile registration device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

32. The method of claim 1, wherein the step of registering local coordinate space pixel positions in each of said plurality of globally recorded three-dimensional measurements and images with corresponding global coordinate space pixel positions, further comprises the steps of:

(i) defining an intra-oral local reference coordinate system associated with each said intra-oral local coordinate space, for each said global position of said measuring and imaging device, whereat are said globally recorded plurality of three-dimensional measurements and images of the intra-oral objects and features;

(ii) assigning intra-oral local space coordinates to each said intra-oral local coordinate space pixel position, for each of said plurality of said globally recorded three-dimensional measurements and images of the intra-oral objects and features;

(iii) transforming said intra-oral local space coordinates of each said intra-oral local coordinate space pixel

position, in each of said plurality of said globally recorded three-dimensional measurements and images of the intra-oral objects and features, to said corresponding or proportionately equivalent said global space coordinates, for forming a plurality of sets of said global coordinate space pixel positions in said global coordinate space which are registered relative to said same intra-oral fixed global registration point; and

(iv) storing said plurality of sets of said global coordinate space pixel positions in said global coordinate space which are registered relative to said same intra-oral fixed global registration point.

33. The method of claim **32**, further comprising applying a standard mathematical or algorithmic coordinate space registration technique for performing said transforming said each intra-oral local coordinate space pixel position to said corresponding or proportionally equivalent global coordinate space pixel position located in said global coordinate space of the oral cavity of the patient.

34. The method of claim **1**, further comprising the step of:

(g) using said registered global coordinate space pixel positions, associated with said plurality of the three-dimensional measurements and images of the intra-oral objects and features located in the oral cavity of the dental patient, for performing a dental procedure on the dental patient.

35. The method of claim **34**, wherein said dental procedure is selected from the group consisting of charting an oral condition, diagnosing an oral condition, and treating an oral condition, of the dental patient.

36. The method of claim **34**, wherein said dental procedure is selected from the group consisting of general dental maintenance, dental mapping, dental surgery, dental restoration, orthodontics, periodontics, occlusal registration, and tempero mandibular joint (TMJ) dysfunction therapies, said dental restoration is applicable to dental prostheses selected from the group consisting of crowns, bridges, dentures, and implants.

37. A system for real time intra-orally acquiring and registering three-dimensional measurements and images of intra-oral objects and features, where the intra-oral objects and features are located inside the oral cavity of a dental patient, comprising:

(a) an intra-oral fixed global registration position inside the oral cavity of the dental patient, said intra-oral fixed global registration position is definable in terms of global coordinate space of the oral cavity, said global coordinate space is associated with a fixed global reference coordinate system, said global coordinate space includes a plurality of intra-oral local coordinate spaces in the oral cavity;

(b) a measuring and imaging device for measuring and imaging the intra-oral objects and features located in the oral cavity, relative to same said intra-oral fixed global registration position; and

(c) a mobile registration device for measuring and recording global positions and orientations of said measuring and imaging device, relative to same said intra-oral fixed global registration position.

38. The system of claim **37**, wherein the intra-oral objects and features are selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside the oral cavity of the dental patient.

39. The system of claim **37**, wherein said global coordinate space features fixed and movable objects, features, devices, instruments, and components, at a location selected from the group consisting of inside the oral cavity and outside the oral cavity.

40. The system of claim **37**, wherein said fixed global reference coordinate system is a curvilinear coordinate system for enabling defining positions in said global coordinate space.

41. The system of claim **37**, wherein each of said plurality of intra-oral local coordinate spaces is associated with an intra-oral local reference coordinate system, said intra-oral local reference coordinate system is a curvilinear coordinate system for enabling defining positions in said intra-oral local coordinate space.

42. The system of claim **37**, wherein said intra-oral fixed global registration position inside the oral cavity of the dental patient, further comprises:

(i) an intra-oral fixed global registration device for measuring and determining distances of said measuring and imaging device to said intra-oral fixed global registration position; and

(ii) an optional substrate for holding said intra-oral fixed global registration device.

43. The system of claim **42**, wherein said intra-oral fixed global registration device includes a mechanism selected from the group consisting of sensing or receiving registration signals and responding to registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

44. The system of claim **42**, wherein said intra-oral fixed global registration device includes a mechanism for transmitting registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

45. The system of claim **42**, wherein said intra-oral fixed global registration device includes a mechanism for locally processing registration signals and for locally programming registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

46. The system of claim **42**, wherein said intra-oral fixed global registration device is designed, configured, and operates according to a category of mechanisms used for measuring distances and recording positions of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms, radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

47. The system of claim **42**, wherein said intra-oral fixed global registration device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

48. The system of claim **42**, wherein said substrate is selected from the group consisting of a single layered configuration and a multi-layered configuration, said configuration features a material composition selected from the group consisting of biological components, chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components.

49. The system of claim 42, wherein said intra-oral fixed global registration device is adapted to be positioned and fixed inside the oral cavity of the dental patient in a form selected from the group consisting of with said substrate and without said substrate.

50. The system of claim 42, wherein said intra-oral fixed global registration device is adapted to be positioned and fixed on an intra-oral object and feature selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside the oral cavity of the dental patient.

51. The system of claim 42, wherein said intra-oral fixed global registration device is adapted to be positioned and fixed inside the oral cavity of the dental patient in a configuration selected from the group consisting of a single layered configuration and a multi-layered configuration, said configuration features a material composition selected from the group consisting of biological components, chemical components, mechanical components, naturally occurring components, synthetically derived components, organic components, and inorganic components.

52. The system of claim 37, wherein said measuring and imaging device is designed and configured for operating at a location selected from the group consisting of inside the oral cavity and outside the oral cavity.

53. The system of claim 37, wherein said measuring and imaging device includes:

(i) standard components and mechanisms for said measuring and imaging the intra-oral objects and features located in the oral cavity;

(ii) a position and orientation guide for three-dimensional maneuvering, guiding, positioning, and orienting said measuring and imaging device throughout said global coordinate space selected from the group consisting of inside the oral cavity and outside the oral cavity, of the dental patient;

(iii) an optional position and orientation guide automatic controller for automatically controlling and communicating with said position and orientation guide; and

(iv) a local measuring and imaging programming and processing unit for locally programming said measuring and imaging of the intra-oral objects and features by locally controlling activation and operation of said measuring and imaging device, and for locally processing measurement and image signals, data, and information relating to the intra-oral objects and features.

54. The system of claim 37, wherein said measuring and imaging device is designed, configured, and operates according to a category of mechanisms used for three-dimensionally measuring and imaging of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms, radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

55. The system of claim 37, wherein said measuring and imaging device is designed, configured, and operates according to a category of electro-optical measuring and imaging techniques selected from the group consisting of time/light in flight, laser scanning, moire, laser speckle pattern sectioning, interferometry, photogrammetry, laser tracking, and, structured light or active triangulation.

56. The system of claim 37, wherein said measuring and imaging device is designed, configured, and operates according to a category of electro-optical measuring and imaging techniques selected from the group consisting of shearography, diffraction grating, digital wavefront reconstruction and wavelength scanning, and conoscopic holography.

57. The system of claim 37, wherein said measuring and imaging device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

58. The system of claim 37, wherein a field of view of said measuring and imaging device is selected from the group consisting of fields of view whereby said intra-oral fixed global registration position is located outside said field of view, and fields of view whereby said intra-oral fixed global registration position is located inside said field of view.

59. The system of claim 37, wherein a field of view of said measuring and imaging device includes intra-oral objects and features selected from the group consisting of a part or entirety of a combination of teeth, gum, intra-oral soft tissue, bone matter, dental undercuts, and, dental fixtures and dental prostheses, permanent or removable, located inside oral cavity of the dental patient.

60. The system of claim 37, whereby selecting a field of view of said measuring and imaging device located at a said global position in said global coordinate space of the oral cavity is performed in a mode selected from the group consisting of manually selecting said field of view and automatically selecting said field of view.

61. The system of claim 37, whereby acquiring at least one three-dimensional measurement and image of the intra-oral objects and features located in a selected field of view of said measuring and imaging device, and, recording said global position of said measuring and imaging device relative to said same intra-oral fixed global registration position, said recording said global position of said measuring and imaging device is performed in a mode selected from the group consisting of synchronously and asynchronously with respect to said acquiring said at least one three-dimensional measurement and image.

62. The system of claim 37, wherein said mobile registration device includes a mechanism selected from the group consisting of sensing or receiving said registration signals and responding to said registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

63. The system of claim 37, wherein said mobile registration device includes a mechanism for transmitting registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

64. The system of claim 37, wherein said mobile registration device includes a mechanism for locally processing said registration signals and for locally programming said registration signals, said registration signals are signals relating to registering said intra-oral local coordinate space with said global coordinate space.

65. The system of claim 37, wherein said mobile registration device is designed, configured, and operates according to a category of mechanisms used for measuring distances and recording positions of objects and features selected from the group consisting of electrical mechanisms, electronic mechanisms, electro-mechanical mechanisms, electro-optical mechanisms, electromagnetic mechanisms,

radar mechanisms, magnetic mechanisms, magneto-mechanical mechanisms, magnetic resonance mechanisms, acoustic mechanisms, ultrasound mechanisms, sonar mechanisms, photo-acoustic mechanisms, telemetry mechanisms, hybrid mechanisms, and combination mechanisms thereof.

66. The system of claim **37**, wherein said mobile registration device is designed, configured, and operates according to a combination of mechanisms selected from the group consisting of analog circuitry, digital circuitry, wireless communications modes, and wired communications modes.

67. The system of claim **37**, wherein data and information extractable from said measuring and imaging the intra-oral objects and features located in the oral cavity relative to said same intra-oral fixed global registration position are used in a dental procedure selected from the group consisting of charting an oral condition, diagnosing an oral condition, and treating an oral condition, of the dental patient.

68. The system of claim **37**, wherein data and information extractable from said measuring and imaging the intra-oral objects and features located in the oral cavity relative to said same intra-oral fixed global registration position are used in a dental procedure selected from the group consisting of general dental maintenance, dental mapping, dental surgery, dental restoration, orthodontics, periodontics, occlusal registration, and tempero mandibular joint (TMJ) dysfunction therapies, said dental restoration is applicable to dental prostheses selected from the group consisting of crowns, bridges, dentures, and implants.

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