# Premarket Approval (PMA) Package for Dockets Management Branch

PMA Number: P950019/S9
Docket # 00M-1212

United Surgical
Ray TFC and Ray TFC Unite Threaded Fusion Cage with Instrumentation

Includes:

Approval Order
Summary of Safety and Effectiveness Data (SSED)
Labeling

00M-1212

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# APPROVAL ORDER

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administration
9200 Corporate Boulevard
Rockville MD 20850

Ms. Jennifer Schuck
Regulatory Affairs Associate
United States Surgical
150 Glover Avenue
Norwalk, Connecticut 06856

MAR 2 2000

Re: P950019/S9
Ray TFC™ and Ray TFC™ Unite Threaded Fusion Cage with Instrumentation
Filed: March 25, 1999
Amended: August 19, September 20, October 19 and December 2, 1999, February 10, 11, 15, 16, 17 and 28, and March 2, 2000

Dear Ms. Schuck:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its review of your premarket approval application (PMA) supplement modifying the indications for use for the Ray TFC and Unite Threaded Fusion Cage with instrumentation. These devices are indicated for use with autogenous bone grafts in patients with degenerative disc disease (DDD) at one or two levels for L2 to S1. These DDD patients may also have up to Grade I spondylolisthesis at the involved level(s). The Ray TFC™ and Ray TCF™ Unite devices are to be implanted via either an open posterior approach or an open anterior approach.

DDD is defined as back pain of discogenic origin with degeneration of the disc confirmed by history and radiographic studies. These patients should be skeletally mature and have six months of non-operative therapy.

The PMA supplement is approved subject to the conditions described below and in the "Conditions of Approval" (enclosed). You may begin commercial distribution of the device as modified upon receipt of this letter.

The sale, distribution, and use of this device are restricted to prescription use in accordance with 21 CFR 801.109 within the meaning of section 520(e) of the Federal Food, Drug, and Cosmetic Act (the act) under the authority of section 515(d)(1)(B)(ii) of the act. FDA has also determined that, to ensure the safe and effective use of the device, the device is further restricted within the meaning of section 520(e) under the authority of section 515(d)(1)(B)(ii) insofar as the sale, distribution, and use must not violate sections 502(q) and (r) of the act.

In addition to the post approval requirements in the enclosure, the post approval reports must include the information outline in the original approval order dated October 26, 1996.

CDRH will notify the public of its decision to approve your PMA by making available a summary of the safety and effectiveness data upon which the approval is based. The information can be found on the FDA CDRH Internet homepage located at http://www.fda.gov/cdrh/pmapage.html. Written requests for this information can also be made to the Dockets Management Branch (HFA-305), Food and Drug Administration, 5630 Fishers Lane, room 1061, Rockville, MD 20852. The written request should include the PMA number or docket number. Within 30 days from the date that this information is placed on the Internet, any interested person may seek review of this decision by requesting an opportunity for administrative review, either through a hearing or review by an independent advisory committee, under section 515(g) of the Federal Food, Drug, and Cosmetic Act (the act).

Failure to comply with the conditions of approval invalidates this approval order. Commercial distribution of a device that is not in compliance with these conditions is a violation of the act.

You are reminded that, as soon as possible and before commercial distribution of your device, you must submit an amendment to this PMA submission with copies of all approved labeling affected by this supplement in final printed form. As part of our reengineering effort, the Office of Device Evaluation is piloting a new process for review of final printed labeling. The labeling will not routinely be reviewed by FDA staff when PMA supplement applicants include with their submission of the final printed labeling a cover letter stating that the final printed labeling is identical to the labeling approved in draft form. If the final printed labeling is not identical, any changes from the final draft labeling should be highlighted and explained in the amendment. Please see the CDRH Pilot for Review of Final Printed Labeling document at http://www.fda.gov/cdrh/pmat/pilotpmat.html for further details.

All required documents should be submitted in triplicate, unless otherwise specified, to the address below and should reference the above PMA number to facilitate processing.

PMA Document Mail Center (HFZ-401)
Center for Devices and Radiological Health
Food and Drug Administration
9200 Corporate Blvd.
Rockville, Maryland 20850

If you have any questions concerning this approval order, please contact Ms. Erin Keith at (301) 594-2036 ext. 122.

Sincerely yours,

James E. Dillard III
Acting Director
Division of General and
Restorative Devices
Office of Device Evaluation
Center for Devices and
Radiological Health

Enclosure

Issued: 3-4-98

## CONDITIONS OF APPROVAL

APPROVED LABELING. As soon as possible, and before commercial distribution of your device, submit three copies of an amendment to this PMA submission with copies of all approved labeling in final printed form to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration (FDA), 9200 Corporate Blvd., Rockville, Maryland 20850.

ADVERTISEMENT. No advertisement or other descriptive printed material issued by the applicant or private label distributor with respect to this device shall recommend or imply that the device may be used for any use that is not included in the FDA approved labeling for the device. If the FDA approval order has restricted the sale, distribution and use of the device to prescription use in accordance with 21 CFR 801.109 and specified that this restriction is being imposed in accordance with the provisions of section 520(e) of the act under the authority of section 515(d)(1)(B)(ii) of the act, all advertisements and other descriptive printed material issued by the applicant or distributor with respect to the device shall include a brief statement of the intended uses of the device and relevant warnings, precautions, side effects and contraindications.

PREMARKET APPROVAL APPLICATION (PMA) SUPPLEMENT. Before making any change affecting the safety or effectiveness of the device, submit a PMA supplement for review and approval by FDA unless the change is of a type for which a "Special PMA Supplement-Changes Being Effected" is permitted under 21 CFR 814.39(d) or an alternate submission is permitted in accordance with 21 CFR 814.39(e). A PMA supplement or alternate submission shall comply with applicable requirements under 21 CFR 814.39 of the final rule for Premarket Approval of Medical Devices.

All situations which require a PMA supplement cannot be briefly summarized, please consult the PMA regulation for further guidance. The guidance provided below is only for several key instances.

A PMA supplement must be submitted when unanticipated adverse effects, increases in the incidence of anticipated adverse effects, or device failures necessitate a labeling, manufacturing, or device modification.

A PMA supplement must be submitted if the device is to be modified and the modified device should be subjected to animal or laboratory or clinical testing designed to determine if the modified device remains safe and effective.

A "Special PMA Supplement - Changes Being Effected" is limited to the labeling, quality control and manufacturing process changes specified under 21 CFR 814.39(d)(2). It allows for the addition of, but not the replacement of previously approved, quality control specifications and test methods. These changes may be implemented before FDA approval upon acknowledgment by FDA that the submission is being processed as a "Special PMA Supplement - Changes Being Effected." This acknowledgment is in addition to that issued by the PMA Document Mail Center for all PMA supplements submitted. This procedure is not applicable to changes in device design, composition, specifications, circuitry, software or energy source.

Alternate submissions permitted under 21 CFR 814.39(e) apply to changes that otherwise require approval of a PMA supplement before implementation of the change and include the use of a 30-day PMA supplement or annual postapproval report. FDA must have previously indicated in an advisory opinion to the affected industry or in correspondence with the applicant that the alternate submission is permitted for the change. Before such can occur, FDA and the PMA applicant(s) involved must agree upon any needed testing protocol, test results, reporting format, information to be reported, and the alternate submission to be used.

POSTAPPROVAL REPORTS. Continued approval of this PMA is contingent upon the submission of postapproval reports required under 21 CFR 814.84 at intervals of 1 year from the date of approval of the original PMA. Postapproval reports for supplements approved under the original PMA, if applicable, are to be included in the next and subsequent annual reports for the original PMA unless specified otherwise in the approval order for the PMA supplement. Two copies identified as "Annual Report" and bearing the applicable PMA reference number are to be submitted to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850. The postapproval report shall indicate the beginning and ending date of the period covered by the report and shall include the following information required by 21 CFR 814.84:

(1) Identification of changes described in 21 CFR 814.39(a) and changes required to be reported to FDA under 21 CFR 814.39(b).

(2) Bibliography and summary of the following information not previously submitted as part of the PMA and that is known to or reasonably should be known to the applicant:

   (a) unpublished reports of data from any clinical investigations or nonclinical laboratory studies involving the device or related devices ("related" devices include devices which are the same or substantially similar to the applicant's device); and

(b) reports in the scientific literature concerning the device.

If, after reviewing the bibliography and summary, FDA concludes that agency review of one or more of the above reports is required, the applicant shall submit two copies of each identified report when so notified by FDA.

ADVERSE REACTION AND DEVICE DEFECT REPORTING. As provided by 21 CFR 814.82(a)(9), FDA has determined that in order to provide continued reasonable assurance of the safety and effectiveness of the device, the applicant shall submit 3 copies of a written report identified, as applicable, as an "Adverse Reaction Report" or "Device Defect Report" to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850 within 10 days after the applicant receives or has knowledge of information concerning:

(1) A mix-up of the device or its labeling with another article.

(2) Any adverse reaction, side effect, injury, toxicity, or sensitivity reaction that is attributable to the device and

(a) has not been addressed by the device's labeling or

(b) has been addressed by the device's labeling, but is occurring with unexpected severity or frequency.

(3) Any significant chemical, physical or other change or deterioration in the device or any failure of the device to meet the specifications established in the approved PMA that could not cause or contribute to death or serious injury but are not correctable by adjustments or other maintenance procedures described in the approved labeling. The report shall include a discussion of the applicant's assessment of the change, deterioration or failure and any proposed or implemented corrective action by the applicant. When such events are correctable by adjustments or other maintenance procedures described in the approved labeling, all such events known to the applicant shall be included in the Annual Report described under "Postapproval Reports" above unless specified otherwise in the conditions of approval to this PMA. This postapproval report shall appropriately categorize these events and include the number of reported and otherwise known instances of each category during the reporting period. Additional information regarding the events discussed above shall be submitted by the applicant when determined by FDA to be necessary to provide continued reasonable assurance of the safety and effectiveness of the device for its intended use.

REPORTING UNDER THE MEDICAL DEVICE REPORTING (MDR) REGULATION. The Medical Device Reporting (MDR) Regulation became effective on December 13, 1984. This regulation was replaced by the reporting requirements of the Safe Medical Devices Act of 1990 which became effective July 31, 1996 and requires that all manufacturers and importers of medical devices, including in vitro diagnostic devices, report to the FDA whenever they receive or otherwise become aware of information, from any source, that reasonably suggests that a device marketed by the manufacturer or importer:

(1) May have caused or contributed to a death or serious injury; or

(2) Has malfunctioned and such device or similar device marketed by the manufacturer or importer would be likely to cause or contribute to a death or serious injury if the malfunction were to recur.

The same events subject to reporting under the MDR Regulation may also be subject to the above "Adverse Reaction and Device Defect Reporting" requirements in the "Conditions of Approval" for this PMA. FDA has determined that such duplicative reporting is unnecessary. Whenever an event involving a device is subject to reporting under both the MDR Regulation and the "Conditions of Approval" for a PMA, the manufacturer shall submit the appropriate reports required by the MDR Regulation within the time frames as identified in 21 CFR 803.10(c) using FDA Form 3500A, i.e., 30 days after becoming aware of a reportable death, serious injury, or malfunction as described in 21 CFR 803.50 and 21 CFR 803.52 and 5 days after becoming aware that a reportable MDR event requires remedial action to prevent an unreasonable risk of substantial harm to the public health. The manufacturer is responsible for submitting a baseline report on FDA Form 3417 for a device when the device model is first reported under 21 CFR 803.50. This baseline report is to include the PMA reference number. Any written report and its envelope is to be specifically identified, e.g., "Manufacturer Report," "5-Day Report," "Baseline Report," etc. Any written report is to be submitted to:

Food and Drug Administration
Center for Devices and Radiological Health
Medical Device Reporting
PO Box 3002
Rockville, Maryland 20847-3002

Copies of the MDR Regulation (FOD # 336&1336)and FDA publications entitled "An Overview of the Medical Device Reporting Regulation" (FOD # 509) and "Medical Device Reporting for Manufacturers" (FOD #987) are available on the CDRH WWW Home Page. They are also available through CDRH's Fact-On-Demand (F-O-D) at 800-899-0381. Written requests for information can be made by sending a facsimile to CDRH's Division of Small Manufacturers Assistance (DSMA) at 301-443-8818.

# SUMMARY OF SAFETY AND EFFECTIVENESS DATA (SSED)

## *SUMMARY OF SAFETY AND EFFECTIVENSS*

## I. GENERAL INFORMATION

| | |
|---|---|
| Device Generic Name: | Intervertebral Body Fusion Device |
| Device Trade Name: | Ray TFC™ Device and<br>Ray TFC Unite™ Device |
| Applicant's Name: | Surgical Dynamics<br>United States Surgical a Division<br>Of Tyco Health Care Group LP<br>150 Glover Avenue<br>Norwalk, CT 06856 |
| Premarket Approval (PMA) #: | P950019/S9 |
| Date of Panel Recommendation: | Panel Tracked[1] |
| Date of Notice of Approval: | March 2, 2000 |

## II. INDICATIONS FOR USE

The Ray TFC™ Device and Ray TFC Unite™ Device are indicated for use with autogenous bone graft in patients with degenerative disc disease (DDD) at one or two levels from L2 to S1. These DDD patients may also have up to Grade I spondylolisthesis at the involved level(s). The Ray TFC™ Device and Ray TFC™ Unite Device may be implanted via an open posterior or an open anterior approach.

DDD is defined as back pain of discogenic origin with degeneration of the disc confirmed by history and radiographic studies. These patients should be skeletally mature and have had six months of non-operative therapy.

## III. DEVICE DESCRIPTION

The Ray TFC™ Device is a hollow, threaded cylinder available in ten sizes. The sizes (diameter x length) are: 12mm x 21mm; 12mm x 26mm; 14mm x 21mm; 14mm x 26mm; 16mm x 21mm; 16mm x 26mm; 18mm x 21mm; 18mm x 26mm; 20mm x 21mm; and 20mm x 26mm. The Ray TFC Unite™ Device is a hollow threaded cylinder with holes that also includes two lateral arcs, which allow closer approximation of two (2) devices in the intervertebral space. The Ray TFC Unite™ Device is also available in ten sizes. The sizes (diameter x length) are:

[1] Panel Tracked PMA supplements involve significant changes to the original approved PMA device, often requiring clinical data, such as additional indications. The Orthopedic and Rehabilitation Advisory Panel (Panel) on a number of occasions have reviewed intervertebral body fusion devices and provided recommendations. Therefore it was not necessary for this particular Panel Tracked Supplement to be reviewed by the Panel.

12mm x 21mm; 12mm x 26mm; 14mm x 21mm; 14mm x 26mm; 16mm x 21mm; 16mm x 26mm; 18mm x 21mm; 18mm x 26mm; 20mm x 21mm; and 20mm x 26mm.

Each device has external 60° threads with flat crests and roots to allow for primary fixation into a pre-tapped intervertebral cavity. Each device also has multiple small transverse holes to enhance bony ingrowth. The Ray TFC™ Device and Ray TFC™ Unite Device is used with anterior and posterior end caps which are available in corresponding diameters of 12mm, 14mm, 16mm, 18mm, and 20mm.

The Ray TFC™ Device and Ray TFC Unite™ Device are manufactured from titanium 6AL-4V (extra low interstitial) alloy which conforms to American society Testing and Materials (ASTM) F136-92. The anterior and posterior end caps are manufactured from ultra-high molecular weight polyethylene (UHMWPE) which conforms to ASTM F648-84. Use of the anterior endcap in the ALIF procedure is optional. The Ray TFC™ Device with end caps and Ray TFC Unite™ Device with end caps are provided sterile.

The Ray TFC™ Device with end caps and the Ray TFC™ Unite Device with end caps are implanted using a defined set of instruments which are available in two categories: size specific and universal. The size specific instruments, which correspond to the diameter of the Ray TFC™ Device and Ray TFC Unite™ Device, include the following: tang retractor; dual tang retractor; vertebral drill; vertebral tap; distractor tips; introducer/obturator; and cage insertion instrument. The universal instruments, which are used regardless of the diameter of the Ray TFC Device or Ray TFC Unite™ Device, include the following: T-handle; end cap insertion instrument, end cap removal instrument; bone packing instrument; distractor handle; impactor cap; vertebral spacers; small/large ganglion retractors; and chisel. All instruments are manufactured from stainless steel that conforms to ASTM F899-94, and are provided nonsterile (must be sterilized prior to use or reuse).

## IV. CONTRAINDICATIONS

The Ray TFC™ Device and Ray TFC Unite™ Device should not be implanted in patients with an active infection at the operative site.

## V. WARNINGS

Implantation of a single cage per involved level is not recommended. The implantation of a single cage has been associated with cage fracture.

## VI. PRECAUTIONS

Prior to use, the physician should be trained in the surgical procedures recommended for the use of this device.

Safety and effectiveness have not been established for patients with the following conditions: previous fusion attempt at the involved level(s), spondylolisthesis greater than Grade I, three or more levels to be fused, concomitant conditions requiring steroids, systemic or terminal illness, active drug abuse, gross obesity, severe osteoporotic conditions and pregnancy.

The Ray TFC™ and Ray TFC Unite™ devices and end caps are packaged sterile. Do not use if the outer package is opened or damaged. Single use only. Do not reuse. Do not resterilize.

Instruments for implantation of the Ray TFC* and Ray TFC Unite* devices and end caps are provided NONSTERILE and must be sterilized prior to use.
Avoid exposure to freezing temperatures, as this could adversely affect the polyethylene end caps.

## VII. ALTERNATIVE PRACTICES AND PROCEDURES

Nonoperative alternative treatments may include, but are not limited to, physical therapy, medications, braces, chiropractic care, or exercise programs. In addition, there are alternative spinal fusion techniques. These include, but are not limited to, posterior lumbar interbody fusion (PLIF) procedures without instrumentation, anterior lumbar interbody fusion (ALIF) procedures without instrumentation, combined anterior and posterolateral (360°) fusion procedures, anterior/anterolateral spinal systems (e.g., plate and screw systems), or posterior spinal systems (e.g., hook and rod systems).

## VIII. POTENTIAL ADVERSE EFFECTS

Two clinical studies using the Ray TFC™ device were completed. The first was a 2-year, multicenter clinical study in which 236 patients underwent surgery, all of which were implanted with the Ray TFC* device via an open posterior approach. The second was a 6-month, multicenter clinical study in which 225 patients under went surgery, of which 224 patients were implanted with the Ray TFC™ device via an open anterior approach. The rates of the complications reported in each study are provided below.

### Operative Complications

Operative complications for implantation of the cages using an open PLIF and an open ALIF surgical approach are presented in Table 1 below. The rates presented are the number of a particular complication divided by the total number of patients in the study (N).

**Table 1 – Operative Complications**

| Complication | PLIF Rate N=236 | ALIF Rate N=225 |
|---|---|---|
| Dural Tear | 9.3% (22/236) | 0 |
| Instrument Malfunctions | 5.1% (12/236)[1] | 0 |
| Improper Device Placement | 4.2% (10/236) | 0 |
| Hemorrhage | 2.1% (5/236) | 4/225 (1.8%) |
| Neural Structure Injury | 0.8% (2/236 | 0 |
| Incorrect Level | 0.4% (1/236) | 0 |
| Vascular Bypass | 0 | 1/225 (0.4%) |
| Pinpoint Laceration of Vena Cava | 0 | 1/225 (0.4%) |
| Incidental Opening of Peritoneum | 0 | 1/225 (0.4%) |
| Supplemental Fixation [2] | 0 | 1/225 (0.4%) |

[1]The instruments have since been redesigned with the intent to simplify their use and to address the reported malfunctions.
[2] See paragraph following Table 2 for definition of supplemental fixation.

The postoperative complications are presented in Tables 2 and 3. In the PLIF study, wound infections, urinary retentions, vertebral spinal fluid (CSF) leakages, soft tissue hematomas, premature ejaculation, malposition, and pneumothorax occurred in the early operative time frame and were transient. In each study (PLIF and ALIF), one patient died of causes unrelated to the device or procedure.

**Table 2 – Postoperative Complications**

| Complication | PLIF N=236 0-2 years | ALIF N[3]=224 0-6 months |
|---|---|---|
| CSF Leak/Dural Tear | 1.3% (3) | 0.4% (1) |
| Death (unrelated to device/procedure) | 0.4% (1) | 0.4% (1) |
| Device Fracture/Collapse/Failure | 0.4% (1) | 0.4% (1) |
| Dislocation of Device | 0 | 0.4% (1) |
| Dislocation of Device End Cap | 0 | 0 |
| Donor Site Infection | 0 | 0.4% (1) |
| Donor Site Pain | 2.1% (5) | 2.2% (5) |
| Epidural Fibrosis | 0.4% (1) | 0 |
| Hematoma | 1.3% (3) | 1.3% (3) |
| Hemorrhage | 0 | 1.3% (3) |
| Hernia | 0 | 1.3% (3) |
| Ileus/Paralytic Ileus | 0.4% (1) | 0.9% (2) |
| Neurological Deficit/Sensory Disturbance/Numbness | 4.7% (11) | 1.3% (3) |
| (Unresolved) Neurological Deficit at Two Years | 2.5% (6) | N/A |
| (Unresolved) Pain at Two Years | 3.0% (7) | N/A |
| Pain Other than Operative Level | 6.4% (15) | 5.8% (13) |
| Pain Related to Operative Level | 6.8% (16) | 10.3% (23) |
| Peritoneal Perforation | 0 | 1.3% (3) |
| Premature Ejaculation | 0.4% (1) | 0 |
| Pneumonia | 0 | 0.4% (1) |
| Pneumothorax | 0.4% (1) | 0 |
| Prolonged Bowel Obstruction | 0 | 0.4% (1) |
| Pseudoarthrosis | 1.3% (3) | 0.4%(1) |
| Retrograde Ejaculation/Loss of Ejaculation | 0 | 0 |
| Surgical Intervention | 3.4% (8)[1] | 5.8% (13)[1] |
| Thrombosis/Thrombophlebitis | 0 | 1.8% (4) |
| Urinary Infection | 0 | 0 |
| Urinary Retention | 0.8% (2) | 1.3% (3) |
| Urological- other | 0 | 1.3% (3) |
| Vessel Damage | 0 | 1.3% (3) |
| Wound Dehiscence | 0 | 1.8% (4) |
| Wound Infection (superficial/deep) | 2.5% (6) | 2.7% (6) |
| Other | 0 | 8.9% (20)[3] |

[1] See Table 3 below

[2] Includes 1 IV site infection/LL lobe atelectasi, 1 unresponsive PCA, 1 MVA, 1 kidney cyst, 1 resting tachycardia, 1 chest pain, 1 confusion, 1 seroma, 1 leg swelling, 1 rectal bleeding, 1 failed back syndrome, 1 non-displaced FX R ant sup ILI, 1 vomiting, 1 gastritis, 1 possible muscle spasm, 1 bone fragment, 1 depression, 1 disc herniation, 1 kidney stones, 1 paraspinous spasm

[3] N does not include the one supplemental fixation patient described in Table 1

**Table 3 – Subsequent surgical Interventions**

| Subsequent Surgical Intervention | PLIF N=236 0-2 years | ALIF N=224 0-6 months |
|---|---|---|
| Removals | 0.4% (1) | 1 (0.4) |
| Revisions | 1.3% (3) | 0 |
| Reoperations | 0 | 5 (2.2) |
| Supplemental Fixations | 1.7% (4) | 7 (3.1) |

A revision is a procedure that adjusts or in any way modifies the original implant configuration (e.g., adjusting position of original configuration, removal with replacement of component). A removal is a procedure that removes one or more components of the original implant configuration without replacement of any components. A reoperation is a procedure that involves any surgical procedure at the involved level(s) that does not remove, modify, or add any components. A supplemental fixation is a procedure in which additional instrumentation not approved as part of the protocol is placed. This may include supplemental placement of a rod/screw system or a plate/screw system.

Patients who had surgical interventions in the PLIF study have already been accounted for in the other complications identified in Tables 1-3 above. The complications that led to these surgical interventions include the following. Three patients underwent revisions: 1) urinary problems led to one device being removed and reimplanted hours post operatively; 2) too small of a device led to it being removed and replaced with a larger device the same day as the original surgery; and 3) improper device placement led to the device being repositioned 40 days postoperatively. One patient underwent a device removal three years postoperatively due to neurological deficit and pain. Four patients under went supplemental fixations to have pedicle screw systems added at 240, 329, 362 and 827 days postoperatively, respectively.

Patients who had surgical interventions in the ALIF study have already been accounted for in the complications identified in Tables 1-3 above. The complications that led to these surgical interventions include the following. Five patients underwent re-operations: 1) spinal cord stimulation was performed 139 days post-operatively, 2) decompression was performed 46 days post-operatively due to pain, 3) re-operation was performed 8 days post-operatively due to neurologic deficit and pain, 4) re-operation was performed 20 days post-operatively to remove a bone fragment, and 5) microdiscectomy was performed 2 days post-operatively to treat a disc herniation. Seven patients underwent supplemental fixations at 62, 84, 87, 144, 159, 161 and 191 days post-operatively, respectively. The patient who received a supplemental fixation at 84 days post-operatively subsequently had the device removed at 224 days past the date of the original surgery. No patients underwent revisions.

## IX. MARKETING HISTORY

The Ray TFC™ Device has been marketed internationally for use in posterior, anterior, and anterior laparoscopic procedures. The Ray TFC™ Device has been marketed in the United States for posterior procedures since October 1996. The Ray TFC™ Unite Device was placed on the market (worldwide) in 1999. Neither the Ray TFC™ Device nor the Ray TFC™ Unite Device has been withdrawn from marketing for any reason relating to its safety or effectiveness.

## X. SUMMARY OF PRECLINCAL STUDIES

Nonclinical tests were conducted to characterize the mechanical properties of the Ray TFC™ Device.

### A. Static Superior-Inferior Compression Testing

***12-18mm Ray TFC™ Devices***

The first set of static compression tests of the Ray TFC™ Device was performed using wood blocks as the vertebral model. Although yield strength (load) is typically defined as stress (load) corresponding to 0.2% of permanent deformation, it was defined as 0.001 inches of permanent deformation, a more conservative estimate of yield strength, in this set of static tests. Five samples of each cage were tested. Except for the 14mm cage, which had one outlier that was not included in the average results, all data are included in the average. The average static yield strengths were:

| Ray TFC™ Size | Static Yield Strength |
|---|---|
| 14mm x 21mm | 2167 ± 142N (487 ± 32lbs) |
| 16mm x 21mm | 2114 ± 138N (475 ± 31lbs) |
| 16mm x 26mm | 2203 ± 93N (495 ± 21lbs) |
| 18mm x 26mm | 2826 ± 312 (635 ± 70lbs) |

A second set of static compression tests were performed using steel blocks as the vertebral model because of the amount of deformation that the oak blocks underwent during compression. Additionally, the static yield load was redefined as 0.2% of permanent deformation. Five samples of each cage were tested. The average static yield strengths were:

| Ray TFC™ Size | Static Yield Strength |
|---|---|
| 12mm x 26mm | 13617 ± 2648N (3060 ± 595lbs) |
| 16mm x 26mm | 10458 ± 1847 (2350 ± 415lbs) |

***20mm Ray TFC™ Devices***

The compressive yield and compressive ultimate strengths of the 20mm Ray TFC™ Device were tested for both cage lengths. The devices were taken to failure, defined as total collapse. The minimum specification to determine acceptance was set at 944lbs (4200 N). The average compressive yield strength for the 20 x 21mm TFC™ was determined to be 5130lbs and the average compressive yield strength for the 20 x 26mm TFC™ was 5280lbs.

***12-20mm Ray TFC™ Unite Devices***

The compressive yield and compressive ultimate strengths of the Ray TFC™ Unite Devices were tested for 12 x 21mm, 16 x 26mm and 20 x 26mm cages. All devices were loaded to failure that was defined as a significant decrease (at least 20%) in load with increasing compressive displacement. The minimum specification to determine acceptance was set at 944lbs (4200 N). The compressive yield strength between the two different cage designs demonstrated equivalence for all sizes that were tested.

## B. Fatigue Testing

***12-18mm Ray TFC™ Devices***

Fatigue testing was performed on the Ray TFC™ Device using oak blocks as vertebral models. All of the tests involved a single cage construct with the end caps in place. There were two sets of fatigue tests, both involved loading the device constructs at 4 Hz. In the first set of tests, the loads were applied without preloading until 10 million cycles were reached or failure (defined as a microfracture). In the second set of tests, the cages which showed microfractures prior to 5 million cycles in the first set of tests were retested past 7 million cycles. This was to show that the devices with microfractures could still be capable of carrying the applied loads.

A total of 38 samples (6-17 samples per cage diameter) were tested. This includes the four (4) cages that were retested. The 12mm, 14mm, and 16mm Ray TFC™ Devices all had fatigue strengths (i.e., endurance limits) of approximately 1335N (300lbs) at cycles ranging from five (5) million to over 15 million. The 18mm Ray TFC™ Device had a fatigue strength of approximately 890N (200lbs) at cycles ranging from eight (8) million to over 15 million. Five (5) million cycles typically represents the number of loading cycles a device might experience within two years. This assumes moderate loading and the device's goal of stabilizing until fusion occurs within those two years. Because of the way the fatigue testing was performed, the endurance limits for each cage size at five (5) million cycles could not be derived. It is expected that if the device was tested in that manner, the endurance limits at five (5) million cycles would be greater than those reported above.

After testing, there were a total of eight (8) of 38 cages with microfractures, but all of the cages stayed intact and were capable of withstanding the applied loading. There were no reported end cap dislodgments. Although the Ray TFC™ Device can be expected to withstand anticipated physiologic fatigue loads, the Ray TFC™ Device should be implanted as a pair based on the resulting fatigue strengths. This is reflected in the Warnings section of the labeling.

***20mm Ray TFC™ Devices***

The fatigue strength was tested to a minimum specification of 337 lbs. or 1500 N. The Ray TFC™ Devices were tested to 5,000,000 fatigue cycles at this load without failure. No fatigue cracks were observed.

***12-20mm Ray TFC™ Unite Devices***

The fatigue strength of three size Ray TFC™ Unite Devices (12 x 21mm, 16 x 26mm and 20 x 26mm) was tested to a minimum specification of 337 lbs. or 1500 N. Six specimens of each size were tested to 5,000,000 fatigue cycles at this load without failure. No fatigue cracks were observed.

**C. Static Closure (End Cap) Testing**

***12-20mm Ray TFC™ Devices and Ray TFC™ Unite Devices***

Static loads were applied to the anterior and posterior end caps to determine the loads required to insert or extract the end caps from the Ray TFC™ Device. Five samples were tested for each Ray TFC™ Device and end cap construct. The average insertion and extraction loads were:

| End Cap | Insertion Force | Extraction Forces |
|---|---|---|
| 14mm (posterior) | 55N (12lbs) | 58N (13lbs) |
| 16mm (posterior) | 68N (15lbs) | 97N (22lbs) |
| 18mm (posterior) | 65N (15lbs) | 112N (25lbs) |
| 14mm (anterior) | Not tested | 85N (19lbs) |
| 16mm (anterior) | Not tested | 212N (48lbs) |
| 18mm (anterior) | Not tested | 138N (31lbs) |

Based on the expected minimal loading on the end cap, the end caps should not become dislodged from the Ray TFC™ Device.

**D. Expulsion Testing/Implant Fixation Strength**

***12-20mm Ray TFC™ Devices and Ray TFC™ Unite Devices***

The loads required to dislodge the Ray TFC™ Device when implanted between two calf vertebrae were measured. Two calf vertebrae and the adjacent disc were potted in cement. Pull-out forces up to 500lbs or until a displacement of 0.01 inch were applied to the device. Five samples of each were tested. The average pull-out strengths were:

| Size | Pull-Out Strength |
|---|---|
| 14mm x 21 mm | 2225N (500lbs) – no failure |
| 16mm x 21mm | 2198N (494lbs) |
| 18mm x 26mm | 2093N (470lbs) |

Loading of this type and magnitude are not expected in the spine where the Ray TFC™ Device is to be placed. Therefore, expulsion of the Ray TFC™ Device is not expected with proper sizing and placement.

## XI. Summary of Clinical Investigations

Clinical studies (PLIF and ALIF) of the Ray TFC™ Device were conducted in accordance with an approved IDE G910006.

### A. Posterior Lumbar Interbody Fusion (PLIF) Study Summary – See the Summary of Safety and Effectiveness for the Original Ray TCF Device (P950019)

### B. Anterior Open Lumbar Interbody Fusion (ALIF-Open) Study Summary

#### 1. ALIF - Objective

The objective of the Ray TFC™ Device ALIF-Open study was to compare the short term safety and effectiveness of the Ray TFC™ Device used in ALIF-Open procedures to that of the Ray TFC™ Device used in PLIF procedures and literature controls.

#### 2. ALIF - Inclusion and Exclusion Criteria

Only those patients who met the inclusion and exclusion criteria were eligible for the study.

Inclusion Criteria

a. Patient must be ≥ 18 years of age.
b. Patient must have symptomatic lumbar degenerative disc disease at one or two levels requiring lumbar interbody fusion at levels L2 to S1. These degenerative disc disease (DDD) patients may also have up to Grade I spondylolisthesis.

c. Symptomatic lumbar degenerative disc disease is defined as back pain of discogenic origin with degeneration of the disc confirmed by history and radiographic evidence (e.g., MRI, CT, etc.) and one or more of the following:
   (i) osteophyte formation;
   (ii) decreased disc height;
   (iii) scarring/thickening of ligamentous tissue;
   (iv) disc herniation; and/or
   (v) facet joint degeneration/changes.
d. These degenerative disc disease patients may also have up to Grade I spondylolisthesis (up to 25% translation of the relative position of one vertebral body to the adjacent vertebral body in the anterior-posterior plane on lateral x-ray, sagittal CT or MRI study).
e. Patients must have completed at least six (6) months of non-operative therapy.
f. Patients who have had one previous surgery at the involved level(s) are eligible for inclusion if the involved level(s) has not had a previous fusion.

Exclusion Criteria

a. The patient has had previous interbody fusion surgery at the operative level(s) of interest.
b. The patient has posterior pathology atypical with DDD.
c. The patient has severe arteriosclerosis of the aorta or iliac vessels.
d. The patient has received radiation treatments to the pelvis or lumbar spine area.
e. The patient has a significant anatomic anomaly or a >10° scoliosis at the operative level(s).
f. The patient is pregnant.
g. The patient has had previous multiple abdominal surgeries.
h. The patient has traumatic instability (e.g., an accident).
i. The vertebral body is fractured.
j. The patient has gross instability of the lumbar spine due to natural causes (greater than Grade I spondylolisthesis).
k. The patient has an active or history of infection at the operative site.
l. The patient has significant endplate sclerosis.
m. The patient is grossly obese.
n. The patient, in the investigators opinion, is physically or mentally compromised (i.e., currently such that the patient is unable to comply with the study requirements, follow-up schedule or give valid informed consent).

o. The patient is unable to comply with the study requirements, rehabilitation program or follow-up schedule.

### 3. ALIF - Patient Population and Demographics

Table 8 depicts the demographic, height, and weight characteristics for the Total Patient Population.

**Table 8 Patient Demographics**

| Patient Characteristic | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Age (years) | 225 | 43.7 | 9.3 | 18.5 | 68.6 |
| Height (inches) | 225 | 67.6 | 3.7 | 59.5 | 77.0 |
| Weight (lbs.) | 225 | 175.4 | 39.4 | 94.0 | 283.0 |

| Variable | n/N | % |
|---|---|---|
| ***Age by Decade*** | | |
| <20 | 1/225 | 0.4% |
| 20-29 | 8/225 | 3.6% |
| 30-39 | 89/225 | 39.6% |
| 40-49 | 72/225 | 32.0% |
| 50-59 | 40/225 | 17.8% |
| 60-69 | 15/225 | 6.7% |
| ***Sex*** | | |
| Male | 106/225 | 47.1% |
| Female | 119/225 | 52.9% |
| ***Race*** | | |
| Caucasian | 204/225 | 90.7% |
| Hispanic | 3/225 | 1.3% |
| Black | 13/225 | 5.8% |
| Asian | 1/225 | 0.4% |
| Other | 4/225 | 1.8% |

Table 9 compares age and gender characteristics for the Total Patient Population to the PLIF Control Group and the Historical Literature Control.

**Table 9 Comparison of Age and Gender Between Test and Control Groups**

| Characteristic | ALIF Open Test Group (N=225) | PLIF Control Group (N=236) | Historical Literature |
|---|---|---|---|
| AGE (years) | 43.7 | 41.4 | 42.7 |
| FEMALE | 52.9% | 37.7% | 41.5% |
| MALE | 47.1% | 62.3% | 58.5% |

The employment history and disease history for the Total Patient Population is presented in Table 10. It should be noted that response categories in this table are not mutually exclusive.

**Table 10 Employment/Disease History**

| CATEGORY | | N | N | % |
|---|---|---|---|---|
| ***Employed*** | | **142** | **225** | **63.1** |
| | Full time | 72 | 225 | 32.0 |
| | Part time | 16 | 225 | 7.1 |
| | Disability | 24 | 225 | 10.7 |
| | Worker's Compensation | 65 | 225 | 28.9 |
| ***Litigation*** | | **9** | **225** | **4.0** |
| | Ongoing | 7 | 225 | 3.1 |
| | Resolved | 2 | 225 | 0.9 |
| ***Worker's Comp/Litigation**** | | **71** | **225** | **31.6** |
| ***Not Employed*** | | **78** | **225** | **34.7** |
| | Homemaker | 19 | 225 | 8.4 |
| | Student | 4 | 225 | 1.8 |
| | Retired | 9 | 225 | 4.0 |
| | Back problems | 46 | 225 | 20.4 |
| | Other medical problems | 4 | 225 | 1.8 |
| ***Disease History*** | | | | |
| | None | 55 | 225 | 24.4 |
| | Cardiac | 22 | 225 | 9.8 |
| | Renal | 8 | 225 | 3.6 |
| | Hypertension | 42 | 225 | 18.7 |
| | Diabetes | 9 | 225 | 4.0 |
| | Rheumatoid arthritis | 4 | 225 | 1.8 |
| | Allergies | 40 | 225 | 17.8 |
| | Cancer | 3 | 225 | 1.3 |
| | Psychiatric | 7 | 225 | 3.1 |
| | Alcoholism | 7 | 225 | 3.1 |
| | Drug Abuse | 5 | 225 | 2.2 |
| | Metabolic | 3 | 225 | 1.3 |
| | Postmenopausal | 11 | 225 | 4.9 |
| | Osteoporosis | 2 | 225 | 0.9 |
| | Skin disorders | 6 | 225 | 2.7 |
| | Respiratory disorder | 20 | 225 | 8.9 |
| | Urogenital disorders | 11 | 225 | 4.9 |
| | Smoking | 79 | 225 | 35.1 |
| | Gastrointestinal disorders | 40 | 225 | 17.8 |
| | Other disease history | 63 | 225 | 28.0 |
| ***Prior Surgery*** | | **88** | **225** | **39.1** |

*Unresolved litigation or worker's compensation

4. **ALIF - Evaluation Schedule**

Patients were evaluated preoperatively, at 6 weeks, 3 months, and 6 months.

Radiographic studies were conducted at 6 months.

5. **ALIF - Patient Accountability**

At the time of database closure, 3/26/99, all 300 patients had been enrolled in the study, with monitored case report forms (CRF's) for the first 242 patients. (This supplement is based upon the results of monitored CRF data only.)

Of these 242 patients, 225 had undergone surgery and 202 had monitored six-month follow-up case report forms available for analysis. The following Table of Patient Accounting (Table 11) depicts the distribution of the first 242 patients with regards to the follow-up regimen.

**Table 11 Table of Patient Accounting**

| | Preop | Op | 6-Wks (3 - 9 wks) | 3-Mo (9 - 17 wks) | 6-Mo (≥ 20 wks) |
|---|---|---|---|---|---|
| **Expected Follow-up** | 242 | 225 | 224 | 223 | 221 |
| **Dropped Prior to Follow-Up** | 17 | | | | |
| **Supplemental Fixation** | | 1 | | | |
| **Lost to Follow-up** | | | 1 | 1 | 4 |
| **Death** | | 0 | 0 | 1* | 0 |
| **Evaluable Patients** | 225 | 224 | 223 | 221 | 217 |
| **Patients with Missed Visit** | | | 9 | 6 | 10 |
| **Visit Outside Follow-Up Window** | | | 7 | 10 | 5 |
| **Available Patients for Analysis** | **225** | **224** | **207** | **205** | **202** |

*Death occurred approximately 89 days after surgery of unrelated causes.

## 6. ALIF - Study Design and Analyses

The study was a prospective, multi-center investigation of the Ray TFC™ Device used in open anterior lumbar interbody fusion (ALIF-Open) procedures. The results of the study were primarily compared to the PLIF patient cohort submitted in the original PMA submission. (The device was approved for use in PLIF procedures on October 29, 1996). The ALIF-Open non-randomized study was designed to be similar to the original PLIF study in order to justify such a comparison.

The ALIF-Open patient cohort was also compared, for informational purposes only, to the literature control detailed in the original PMA submission. Per the original PMA submission, the English language medical literature published from January 1966 through January 1995 was searched to locate all relevant articles. The MEDLINE database was searched by using the key words "lumbar" and "fusion". In addition, all potentially relevant articles from bibliographies in retrieved articles as well as textbooks were reviewed.

## 7. ALIF - Effectiveness Analyses

The effectiveness variables included an assessment of fusion at the involved level(s), pain, function, and muscle strength. In some cases, only partial data was available (i.e., not all of the four outcome measures were obtained for all patients at all follow-up points). In these cases, patients without data were considered failures. Therefore, all patients who had a follow-up visit, whether all outcome measures were assessed or not, are accounted for in the success rates. Because all of the patients had reached their six month postoperative time points, the effectiveness analyses involved the six month time points.

## 8. ALIF - Effectiveness Analyses Fusion

Successful fusion was defined as no motion on flexion/extension x-rays, no halo around the implant, no bone sclerosis around the implant, and increased or maintained bony density within the implant. All four of the criteria had to be met for successful fusion. In cases where two levels were implanted, both levels must have been fused in order for that patients to be considered successfully fused. The successful fusion rate at 6 months was 81.7% (165/202).

## 9. ALIF - Effectiveness Analysis Clinical Outcomes (pain, function, and muscle strength)

Pain was measured on the Prolo Scale. The "functional" grade of the Prolo Scale ranks the pain responses and effect of pain on activities of daily living. This portion of the Prolo Scale is a 5-point scale where F1 = total incapacitation, F2 = mild to moderate level of low back pain and/or sciatica, F3 = low level of pain but able to perform all activities except sports (use of occasional prescription analgesics), F4 = no pain but has one or more recurrences of low back pain or sciatic (occasional over-the-counter analgesics), and F5 = complete recovery and able to perform all previous sports activities.

All patients experiencing an improvement by at least one level in the pain score relative to their preoperative score were considered to have a successful result in terms of the pain outcome measure.

Like the pain parameter, function was also measured on the Prolo Scale. The "economic" grade of the Prolo Scale expresses the patient's capacity for gainful employment or alternative comparable pursuits (e.g., housework, retirement activities, etc.). This portion of the Prolo Scale is a 5-point scale where E1 = complete invalid; E2 = no gainful occupation (capable of independent locomotion and self care, but unable to hod job, perform housework, attend school, or continue retirement activities); E3 = able to work (attend school, participate in retirement activities, do housework) but not at previous occupation or level of activity; E4 = working at previous occupation on part-time or modified status (attending school, doing housework, performing retirement activities); and E5 = able to work at previous occupation without any restrictions (attend school, do housework, perform retirement activities).

Every patient maintaining or experiencing an improvement by at least one point in the function score relative to his/her preoperative score was considered to have a successful result in terms of the function outcome measure.

Muscle strength was evaluated bilaterally at eight sites: hip flexion, hip extension, hip abduction, knee flexion, knee extension, ankle plantarflexion, and ankle dorsiflexion. Each of the sites was measured on a 6-point scale ranging from 0 (no evidence of contractility) to 5 (complete motion against gravity, full resistance).

Maintenance or improvement in mean muscle strength score was required in order for the patient to be considered a success.

A composite clinical endpoint combines the two scales of the Prolo instrument with muscle strength. The paired measurements were compared at baseline and six months. The composite measure consisted of improvement in pain (Prolo functional scale), maintained or improved function (Prolo economic scale) and increased muscle

strength. The composite summary indicates that nearly two-thirds of the study patients (126/196 or 64.3%) exhibited successful outcomes on all three component parts of the composite endpoint.

## 10. ALIF - Safety Analysis

Safety Analyses included all patients (excluding the patient requiring supplemental fixation) regardless of the completeness of their follow-up data. Safety was assessed through physical examinations, x-rays, and by questioning of all patients enrolled in the study. For a summary of the safety data, please see Tables 1-3 in Section VIII above, Potential Adverse Effects.

The experience in this clinical investigation with the Ray TFC™ Device compares favorably with literature complication rates for ALIF's. Reported complications for the Ray TFC™ Device were within the range reported for the literature control groups as identified in Table 12.

**Table 12 Post-Operative Complications**

| Complication | ALIF N=224 0-6 months (total # events) | ALIF Lit Control N=varies 0-27 years (# of articles out of 31 reporting the complication) |
|---|---|---|
| CSF Leak/Dural Tear | 0.45% (1) | Not Reported |
| Death (unrelated to device/procedure) | 0.45% (1) | 0.4% - 3.1%[5] (3) |
| Device Fracture/Collapse/Failure | 0.45% (1) | 4.6% - 5.7% (2) |
| Dislocation of Device | 0.45% (1) | 0.4% - 2.9% (5) |
| Dislocation of Device End Cap | 0 | Not Reported |
| Donor Site Infection | 0.45% (1) | 9.3% (1) |
| Donor Site Pain | 2.23% (5) | 0.7% - 37.1% (5) |
| Embolism | 0 | 0.9% - 6.1% (6) |
| Epidural Fibrosis | 0 | Not Reported |
| Hematoma | 1.34% (3) | 2.8% (1) |
| Hemorrhage | 1.34% (3) | 1.0% (1) |
| Hernia | 1.34% (3) | 0.5% - 3.7% (3) |
| Ileus/Paralytic Ileus | 0.89% (2) | 2.0% - 8.2% (7) |
| Neurological Deficit/Sensory Disturbance/Numbness | 1.34% (3) | 2.0% - 32.1% (10) |
| (Unresolved) Neurological Deficit at Two Years | N/A | Not Reported |
| (Unresolved) Pain at Two Years | N/A | Not Reported |
| Pain Other than Operative Level | 5.8% (13) | 19.1% - 77.9% (7) |

| Complication | ALIF N=224 0-6 months (total # events) | ALIF Lit Control N=varies 0-27 years (# of articles out of 31 reporting the complication) |
|---|---|---|
| Pain Related to Operative Level | 10.27% (23) | 13.9% - 107.5% [7] (19) |
| Peritoneal Perforation | 1.34% (3) | Not Reported |
| Premature Ejaculation | 0 | Not Reported |
| Pneumonia | 0.45% (1) | 1.0% - 2.8% (2) |
| Pneumothorax | 0 | Not Reported |
| Prolonged Bowel Obstruction | 0.45% (1) | Not Reported |
| Pseudoarthrosis | 0.45%(1) | Not Reported |
| Retrograde Ejaculation/Loss of Ejaculation | 0 | 1.0% - 3.0% (8) |
| Surgical Intervention | 5.8% (13)[1] | 1.9% - 25.9% (10) |
| Thrombosis/Thrombophlebitis | 1.79% (4) | 2.2% - 11.2% (10) |
| Urinary Infection | 0 | 2.8% - 27.8% (6) |
| Urinary Retention | 1.34% (3) | |
| Urological- other | 1.34% (3) | 1.0% (1) |
| Vessel Damage | 1.34% (3) | 1.4% - 2.2% (2) |
| Weakness | 0 | 2.4% (1) |
| Wound Dehiscence | 1.79% (4) | 2.8% (1) |
| Wound Infection (superficial/deep) | 2.68% (6) | 1.9% - 5.3% (8) |
| Other | 8.93% (20)[3] | 0.4% - 6.0%[4] (11) |

[1] See Table 3 below

[2]Includes 0 revisions, 7 removals, 84 reoperations, and 0 supplemental fixations.

[3]Includes 1 IV site infection/LL lobe atelectasi, 1 inicisional hernia, 1 unresponsive PCA, 1 MVA, 1 kidney cyst, 1 sensory loss left leg/geni nerve, 1 resting tachycardia, 1 chest pain, 1 confusion, 1 seroma, 1 leg swelling, 1 rectal bleeding, 1 failed back syndrome, 1 non-displaced FX R ant sup ILI, 1 vomiting, 1 gastritis, 1 possible muscle spasm, 1 bone fragment, 1 depression, 1 disc herniation, 1 kidney stones, 1 paraspinous spasm

[4]Includes 1 wrong level, 2 heart attacks, 2 arachnoiditis, 4 atelectasis, 1 diskitis, 6 graft instability/resportion, 1 retained sponge, 9 serum hepatitis, 5 edema, 3 genital dysfunction/impotence, 14 bed sores, 1 keloid scar, 2 recurrent disc herniation

[5]Excludes Supplemental Fixation reported in Table 1

[6]Reported Range of Complication in ALIF literature.

[7]Total number of events is cumulative at any given time point, therefore the rate exceeded 100%.

## 11. ALIF - Study Success / Statistical Differences

To be considered an overall study success, the patient must have met each of the following four criteria: 1) fusion of the involved level(s); 2) improvement in pain; 3) maintenance or improvement in function; and 4) maintenance or improvement in muscle strength. The success

rates at 6 months are shown in Table 13 with the PLIF data at 6 months for comparison.

**Table 13 – Study Success Rates at 6 Months**

| Success Criteria | ALIF[1] Rate | PLIF[1] Rate |
|---|---|---|
| Fusion Rate | 82% (160/202) | 73% (163/223) |
| Clinical Outcomes | 62% (126/202) | 63% (141/223) |
| Overall Success (meet all above) | 54% (109/202) | 48% (108/223) |

[1] 202 patients in the ALIF and 223 patients in the PLIF study were available for analysis at the 6-moth follow-up. Patients who were present for the follow-up visit, but who did not receive assessment of fusion, or clinical outcomes, or both, were reported as failures in Table 13.

## XII. SUMMARY OF OTHER CLINICAL INVESTIGATIONS

Prior to the submission of any IDE, one of the primary investigators for the IDE study implanted prototypes of the Ray TFC™ Device into 10 patients under the sponsorship of another company. The patients were diagnosed as having DDD requiring posterior lumbar interbody fusion (PLIF). Four of the devices were made from stainless steel and six were made from commercially pure titanium. The report of clinical and radiographic results was essentially incomplete and anecdotal. The fusion rate was reported as 91% at one year and 88% at five years. Complications included a dural tear, CSF leak, and stress cracks in the cages.

## XIII. CONCLUSIONS DRAWN FROM THE STUDIES

The nonclinical (i.e., mechanical) and clinical data provide reasonable assurance of the safety and effectiveness of the Ray TFC™ Device and Ray TFC™ Unite Device for the treatment of degenerative disc disease (DDD), when used as indicated.

## XIV. PANEL RECOMMENDATIONS

The Orthopedic and Rehabilitation Devices Panel (Panel) did not meet to discuss the Ray TFC and Unite devices implanted using an open ALIF procedure. FDA determined that the Panel had provided sufficient guidance on intervertebral body fusion devices through the numerous Panel meetings where interbody fusion devices were discussed.

## XV. CDRH DECISION

CDRH issued and approval order on March 2, 2000 for the Ray TFC™ Device and the Ray TFC Unite™ Device used in ALIF procedures.

## XVI. APPROVAL SPECIFICATIONS

Directions for Use: See labeling.

Hazards to Health from Use of the Device: See indications, contraindications, warnings, precautions, and adverse events in labeling.

Post-approval Requirements and Restrictions: See approval order.

## XVII. REFERENCES FOR CONTROLS

*PLIF*

See the Summary of Safety and Effectiveness for the original Ray TCF Device approved on October 29, 1996.

*ALIF*


Blumenthal, SL, Baker J, Dosett A, Selby DK. The role of anterior lumbar fusion for internal disc disruption. *Spine* 13(5): 566-9, 1988.

Calandruccio RA and Benton BF. Anterior lumbar fusion. *Clin Orthop* 35: 63-8: 1964.

Cheng CL, Fang D, Lee PC, Leong JC. Anterior spinal fusion for spondylolysis and isthmic spondylolisthesis. *J of Bone and Joint Surg (Br)* 71, 264-7, 1989.

Chow SP, Leong JC, Ma A, Yau A. Anterior spinal fusion for deranged lumbar intervertebral disc: a review of 97 cases. *Spine* 5(5): 452-8, 1980.

Cleveland M, Bosworth DM, and Thompson FR. Pseudoarthrosis in the lumbosacral spine. *J Bone Joint Surg* 30A: 302-11, 1948.

Cloward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion: Indications, operative technique, after-care. *J Neurosurgery* 10:154-68, 1953.

Dennis S, et.al. Comparison of disc space height after anterior lumbar interbody fusion. *Spine* 14(8): 876-8, 1989.

Flynn JC and Hoque A. Anterior fusion of the lumbar spine. *J of Bone and Joint Surg.* 61:1143-50, 1979.

Freebody D, Bendall R, Taylor RD. Anterior transperitoneal lumbar fusion. *J of Bone and Joint Surg.* 53B:61-7, 1971.

Frymoyer JW, Hanley E, Howe J, Kuhlmann D, Matteri R. Disc excision and spine fusion in the management of lumbar disc disease: a minimum 10 year follow up. *Spine* 3(1): 1-6, 1978.

Fujimaki A and Crock HV. The results of 150 anterior lumbar interbody fusion operations performed by two surgeons in Australia. *Clin Orthop* 165:164-7, 1982.

Gill K and Blumenthal SL. Functional results after anterior lumbar fusion at L5-S1 in patients with normal and abnormal MRI scans. *Spine* 17(8):940-2, 1992.

Goldner L et.al. Anterior disc excision and interbody spinal fusion for chronic low back pain. *Orthopedic Clinics of North America*, 2: 510-68, 1971.

Greenough, C. Anterior lumbar fusion: a comparison of non-compensation patients with compensation patients. *Clinical Orthopaedics and Related Research* 300: 30-7, 1994.

Harmon PH. Anterior disc excision and fusion of the lumbar vertebral bodies, a review of diagnostic level testing with operative results in more than seven hundred cases. *J of Intl College of Surgeons* 40(6): 572-86, 1963.

Hoover NW. Methods of lumbar fusion. *J of Bone and Joint Surg* 50: 194-210.

Inoue S, Watanabe T, Hirose A. Anterior discectomy and interbody fusion for lumbar disc herniation. *Clin Orthop* 183: 22-31, 1984.

Kim NH, Kim HK, Suh JS. A computed tomographic analysis of changes in the spinal canal after anterior lumbar interbody fusion. *Clin Orthop and Related Research* 286: 180-91, 1993.

Knox B and Chapman T. Anterior lumbar interbody fusion for discogram concordant pain. *J of Spinal Disorders* 6:242-4, 1993.

Lane JD and Moore ES. Transperitoneal approach to the intervertebral disc in the lumbar area. *Ann Surg* 127: 537-51, 1948.

Lehmann TR, Spratt KF, Tozzi JE, Weinstein JN, Reinarz SJ, El-Khoury GY, Colby H. Long term follow up of lower lumbar fusion patients. *Spine* 12(2): 97-104, 1987.

Leong JCY, Hooper G, Fang D, Chun SY. Disc excision and the anterior spinal fusion for lumbar disc protrusion in the adolescent. *Spine* 7(6):623-6, 1982.

Leong JCY, Chun SY, Grange WJ, Fang D. Long term results of lumbar intervertebral disc prolapse. *Spine* 8(7):793-9, 1983.

Lojuidice VA et.al. Anterior lumbar interbody fusion. *Spine* 13(3):366-9, 1988.

Newman MH and Grinstead GL. Anterior lumbar interbody fusion for internal disruption. *Spine* 17(7): 831-3, 1992.

Raugstad TS et.al. Anterior interbody fusion of the lumbar spine. *Clin Orthop Scand* 53:561-5, 1982.

Sorensen KH. Anterior interbody lumbar spine fusion for incapacitating disc degeneration and spondylolisthesis. *Acta Orthop Scand* 49: 267-77, 1978.

Stauffer RN and Coventry MB. Anterior interbody lumbar spine fusion. *J of Bone and Joint Surg* 54A: 756-68, 1972.

Takahashi K et.al. Long term results of anterior interbody fusion for treatment of degenerative spondylolisthesis. *Spine* 15(11):1211-13, 1990.

Thomsen E. Intercorporal lumbar spondylosis. *Acta Orthop Scand* 56:287-93.

# LABELING

**Surgical Dynamics***
**RAY TFC* and Ray TFC Unite* Device**

## Device Description

### Ray TFC* Device

The Ray TFC* Device is a hollow threaded cylinder with holes. It is available in ten sizes, with 5 diameters (12 mm, 14 mm, 16 mm, 18 mm, and 20 mm) and 2 lengths (21 mm or 26 mm).

### Ray TFC Unite* Device

The Ray TFC Unite* Device is a hollow threaded cylinder with holes. The Ray TFC Unite* Device also includes two lateral arcs, which allow closer approximation of two (2) devices in the intervertebral space. It is available in ten sizes, with 5 diameters (12 mm, 14 mm, 16 mm, 18 mm, and 20 mm) and 2 lengths (21 mm or 26 mm).

Both the Ray TFC* Device and the Ray TFC Unite* Device are composed of Titanium 6Al-4V (extra low interstitial) alloy, which conforms to the American Society for Testing and Materials (ASTM) F136-92. The Ray TFC* and Ray TFC Unite* devices are used with anterior and posterior end caps (use of the anterior end cap in ALIF procedures is optional), which are available in corresponding diameters of 12 mm, 14 mm, 16 mm, 18 mm and 20 mm. The end caps are composed of ultra-high-molecular weight polyethylene (UHMWPE) which conforms to ASTM F648-84.

The Ray TFC* and Ray TFC Unite* devices and endcaps are implanted using a set of stainless steel instruments whose material conforms to ASTM F899-94. Refer to the Surgical Technique Manual or the individual instrument package insert for a full description of these instruments and their cleaning and sterilization instructions.

## Indications

The Ray TFC* and Ray TFC Unite* devices are indicated for use with autogenous bone graft in patients with degenerative disc disease (DDD) at one or two levels for L2 to S1. These DDD patients may also have up to Grade I spondylolisthesis at the involved level(s). The Ray TFC* and Ray TFC Unite* devices are to be implanted via either an open posterior approach or an open anterior approach. DDD is defined as back pain of discogenic origin with degeneration of the disc confirmed by history and radiographic studies. These patients should be skeletally mature and have six months of nonoperative therapy.

## Contraindications

The Ray TFC* and Ray TFC Unite* devices should not be implanted in patients with an active infection at the operative site.

## Warnings

Implantation of a single cage per involved level is not recommended. The implantation of a single cage has been associated with cage fracture.

## Precautions

•Prior to use, the physician should be trained in the surgical procedure recommended for the use of this device.

•Safety and effectiveness have not been established for patients with the following conditions: previous fusion attempt at the involved level(s), spondylolisthesis greater than Grade I, three or more levels to be fused, concomitant conditions requiring steroids, systemic or terminal illness, active drug abuse, gross obesity, severe osteoporotic conditions and pregnancy.

•The Ray TFC* and Ray TFC Unite* devices and end caps are packaged sterile. Do not use if the outer package is opened or damaged. Single use only. Do not reuse. Do not resterilize.

•Instruments for implantation of the Ray TFC* and Ray TFC Unite* devices and end caps are provided NONSTERILE and must be sterilized prior to use.

•Avoid exposure to freezing temperatures, as this could adversely effect the polyethylene end caps.

## Adverse Events

Two clinical studies using the Ray TFC* device were completed. The first was a 2-year, multicenter clinical study in which 236 patients underwent surgery, all of which were implanted with the Ray TFC* device via an open posterior approach. The second was a 6-month, multicenter clinical study in which 225 patients under went surgery, of which 224 patients were implanted with the Ray TFC* device via an open anterior approach. The rates of the complications reported in each study are provided below.

## Operative Complications

Operative complications for implantation of the cages using an open PLIF and an open ALIF surgical approach are presented in Table 1 below. The rates presented are the number of a particular complication divided by the total number of patients in the study (N).

**TABLE 1 Operative Complications**

| Complication | PLIF Rate N=236 | ALIF Rate N=225[2] |
|---|---|---|
| Dural Tear | 9.3% (22/236) | 0 |
| Instrument Malfunctions | 5.1% (12/236)[1] | 0 |
| Improper Device Placement | 4.2% (10/236) | 0 |
| Hemorrhage | 2.1% (5/236) | 1.8% (4/225) |
| Neural Structure Injury | 0.8% (2/236) | 0 |
| Incorrect Level | 0.4% (1/236) | 0 |
| Vascular Bypass | 0 | 0.4% (1/225) |
| Pinpoint Laceration of Vena Cava | 0 | 0.4% (1/225) |
| Incidental Opening of Peritoneum | 0 | 0.4% (1/225) |
| Supplemental Fixation[3] | 0 | 0.4% (1/225) |

[1]The instruments have since been redesigned with the intent to simplify their use and to address the reported malfunctions.
[2]Total number of patients at operative time point was 225 for the ALIF study.
[3] Supplemental Fixation is a procedure in which additional instrumentation not under study in the protocol is implanted.

## Postoperative Complications

Postoperative complications are presented below in Tables 2 and 3. These complications have been recorded through 24 months for PLIF and 6 months for ALIF-Open. The rates presented are the number of patients with a particular complication divided by the total number of patients in the study (N).

**TABLE 2 Post-Operative Complications**

| Complication | PLIF N=236 0-2 years (cumulative # events) | ALIF N[5]=224 0-6 months (cumulative # events) | ALIF Lit Control N= varied 0-27 years (# articles out of 31 reporting complication) |
|---|---|---|---|
| CSF Leak/Dural Tear | 1.27% (3) | 0.45% (1) | Not Reported |
| Death (unrelated to device/procedure) | 0.42% (1) | 0.45% (1) | 0.4% - 3.1%[6] (3) |
| Device Fracture/Collapse/Failure | 0.42% (1) | 0.45% (1) | 4.6% - 5.7% (2) |
| Dislocation of Device | 0 | 0.45% (1) | 0.4% - 2.9% (5) |
| Dislocation of Device End Cap | 0 | 0 | Not Reported |
| Donor Site Infection | 0 | 0.45% (1) | 9.3% (1) |
| Donor Site Pain | 2.12% (5) | 2.23% (5) | 0.7% - 37.1% (5) |
| Embolism | 0 | 0 | 0.9% - 6.1% (6) |
| Epidural Fibrosis | 0.42% (1) | 0 | Not Reported |
| Hematoma | 1.27% (3) | 1.34% (3) | 2.8% (1) |
| Hemorrhage | 0 | 1.34% (3) | 1.0% (1) |
| Hernia | 0 | 1.34% (3) | 0.5% - 3.7% (3) |
| Ileus/Paralytic Ileus | 0.42% (1) | 0.89% (2) | 2.0% - 8.2% (7) |
| Neurological Deficit/Sensory Disturbance/Numbness | 4.66% (11) | 1.34% (3) | 2.0% - 32.1% (10) |
| (Unresolved) Neurological Deficit at Two Years | 2.54% (6) | N/A | Not Reported |
| (Unresolved) Pain at Two Years | 3.0% (7) | N/A | Not Reported |
| Pain Other than Operative Level | 6.36% (15) | 5.8% (13) | 19.1% - 77.9% (7) |
| Pain Related to Operative Level | 6.78% (16) | 10.27% (23) | 13.9% - 107.5% [7] (19) |
| Peritoneal Perforation | 0 | 1.34% (3) | Not Reported |
| Premature Ejaculation | 0.42% (1) | 0 | Not Reported |
| Pneumonia | 0 | 0.45% (1) | 1.0% - 2.8% (2) |
| Pneumothorax | 0.42% (1) | 0 | Not Reported |
| Prolonged Bowel Obstruction | 0 | 0.45% (1) | Not Reported |
| Pseudoarthrosis | 1.27% (3) | 0.45%(1) | Not Reported |
| Retrograde Ejaculation/Loss of Ejaculation | 0 | 0 | 1.0% - 3.0% (8) |
| Surgical Intervention | 3.39% (8)[1] | 5.8% (13)[1] | 1.9% - 25.9% (10) |
| Thrombosis/Thrombophlebitis | 0 | 1.79% (4) | 2.2% - 11.2% (10) |
| Urinary Infection | 0 | 0 | 2.8% - 27.8% (6) |
| Urinary Retention | 0.85% (2) | 1.34% (3) | |
| Urological- other | 0 | 1.34% (3) | 1.0% (1) |
| Vessel Damage | 0 | 1.34% (3) | 1.4% - 2.2% (2) |
| Weakness | 0 | 0 | 2.4% (1) |
| Wound Dehiscence | 0 | 1.79% (4) | 2.8% (1) |
| Wound Infection (superficial/deep) | 2.54% (6) | 2.68% (6) | 1.9% - 5.3% (8) |
| Other | 0 | 8.93% (20)[3] | 0.4% - 6.0%[4] (11) |

[1] See Table 3 below

[2] Includes 0 revisions, 7 removals, 84 reoperations, and 0 supplemental fixations.

[3] Includes 1 IV site infection/LL lobe atelectasi, 1 inicisional hernia, 1 unresponsive PCA, 1 MVA, 1 kidney cyst, 1 sensory loss left leg/geni nerve, 1 resting tachycardia, 1 chest pain, 1 confusion, 1 seroma, 1 leg swelling, 1 rectal bleeding, 1 failed back syndrome, 1 non-displaced FX R ant sup ILI, 1 vomiting, 1 gastritis, 1 possible muscle spasm, 1 bone fragment, 1 depression, 1 disc herniation, 1 kidney stones, 1 paraspinous spasm

[4]Includes 1 wrong level, 2 heart attacks, 2 arachnoiditis, 4 atelectasis, 1 diskitis, 6 graft instability/resportion, 1 retained sponge, 9 serum hepatitis, 5 edema, 3 genital dysfunction/impotence, 14 bed sores, 1 keloid scar, 2 recurrent disc herniation

[5]Excludes Supplemental Fixation reported in Table 1

[6]Reported Range of Complication in ALIF literature.
[7]Total number of events is cumulative at any given time point, therefore the rate exceeded 100%.

**Table 3 Subsequent Surgical Interventions**

| Subsequent Surgical Intervention | PLIF N=236 over 2 years (cumulative # events) | ALIF N[8]=224 over 6 months (cumulative # events) |
|---|---|---|
| Removals[9] | 0.4% (1) | 0.4%(1) |
| Revisions[10] | 1.3% (3) | 0% |
| Reoperations[11] | 0% | 2.2%(5) |
| Supplemental Fixations[12] | 1.7% (4) | 3.1%(7) |

[8]N excludes the one supplemental fixation patient included in Table 1.

[9]Removal is a procedure where *all* of the original system configuration is removed with or without replacement
[10] Revision is a procedure that adjusts or in any way modifies or removes *part* of the original implant configuration, with or without replacement of a component. A revision may also include adjusting the position of the original configuration.
[11] Reoperation is any surgical procedure at the involved level(s) that does not involve removal, modification, or addition of any components to the system
[12]Supplemental Fixation is a procedure in which additional instrumentation not under study in the protocol is implanted.

## Clinical Results

The following are clinical results of the same multi-center studies presented above. The success rates are for overall success as well as for each of the four major individual measures of success. Overall success was defined as fusion at the involved level(s); improvement in pain; maintenance or improvement in function; and maintenance or improvement in muscle strength. Note that actual number of patients with data available differs slightly for each success criteria based on study follow-up.

It should be noted that fusion is defined as follows: no motion on superimposition of flexion and extension x-rays, as corroborated by the absence of halo around the implant, the absence of bone sclerosis, and the maintenance or increase in bone density within the device.

**TABLE 4 Summary of Clinical Results**

| SUCCESS PARAMETERS | PLIF At 2 Years | |
|---|---|---|
| **OVERALL SUCCESS (MET ALL 4 BELOW)** | **128/199** | **64%** |
| FUSION RATE | 183/200 | 92% |
| MUSCLE STRENGTH MAINTENANCE OR IMPROVEMENT | 197/208 | 95% |
| FUNCTION MAINTENANCE OR IMPROVEMENT | 200/209 | 96% |
| PAIN IMPROVEMENT | 158/209 | 76% |

| SUCCESS PARAMETERS | ALIF[1] At 6 Months | | PLIF[1] At 6 Months | |
|---|---|---|---|---|
| **OVERALL SUCCESS (MET FUSION & CLINICAL OUTCOMES)** | **109/202**** | **54%** | **108/223**** | **48%** |
| FUSION RATE | 165/202 | 82% | 163/223 | 73% |
| 3 CLINICAL OUTCOMES[2] | 126/202 | 62% | 141/223 | 63% |

[1] 202 patients in the ALIF study and 223 patients in the PLIF study were available for analysis at the 6-month follow-up. Patients who were present for the follow-up, but who did not receive assessments of fusion, or clinical outcomes, or both were reported as failures in this table.
[2] 3 Clinical Outcomes include muscle strength maintenance or improvement, function maintenance or improvement, and pain improvement.

From the PLIF clinical study, the following statistical differences were observed up to or at the 2-year time point:

• Younger patients had lower levels of pain and higher levels of function than older patients.

• Nonsmokers had lower levels of pain and higher levels of function than smokers.

• Patients with baseline disc herniation had lower levels of pain than those without baseline disc herniation.

• Older patients with L5-S1 involvement had higher levels of pain than older patients with other levels of involvement. In younger patients, there was no significant effect on pain based on level of involvement.

• Patients who had lower baseline function scores showed lower levels of function through the study than those with higher baseline scores.

• Older patients with L5-S1 involvement had lower levels of function than older patients with other levels of involvement. Additionally, older patients with lower baseline function scores had lower levels of function than older patients with higher baseline function scores. In younger patients, there was no significant effect on function based on level of involvement or baseline function score.

CAUTION: U.S. federal law restricts this device to sale by or on the order of a physician with appropriate training or experience.

Device Retrieval Efforts

Should it be necessary to remove a Ray TFC* or Ray TFC Unite* device, please call Surgical Dynamics, Inc. at the number below to receive manufacturer's instructions regarding data collection, including histopathological, mechanical and adverse event information.

Ordering Information

The Ray TFC* and Ray TFC Unite* devices can be ordered from your distributor, or contact:

Surgical Dynamics, Inc. 150 Glover Avenue, Norwalk, CT 06856 USA (800) 822-4734 or (203) 845-1000.

Tyco Healthcare UK Ltd., Gosport, PO13, OAS, UK

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