

SUMMARY OF SAFETY AND EFFECTIVENESS

I. GENERAL INFORMATION

Device Generic Name: Intervertebral Body Fusion Device

Device Trade Name: Ray TFC™ Device and
Ray TFC Unite™ Device

Applicant's Name: Surgical Dynamics
United States Surgical a Division
Of Tyco Health Care Group LP
150 Glover Avenue
Norwalk, CT 06856

Premarket Approval (PMA) #: P950019/S9

Date of Panel Recommendation: Panel Tracked¹

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 underwent 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%)

¹The 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=238 0-2 years	ALIF N=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=238 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 underwent 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 PRECLINICAL 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 $>10^\circ$ 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 hold 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% ^b (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 incisional 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 ILL, 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/resorption, 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-month 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

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