

LASERS IN DENTISTRY

Proceedings of the International Congress
of Laser in Dentistry,
Tokyo, Japan, 5-6 August 1988



Editors:

HAJIME YAMAMOTO
KAZUHIKO ATSUMI
HARUKA KUSAKARI

Associate Editors:

MICHIO SHIMAKURA
TERUO KAYANO



1989

EXCERPTA MEDICA, Amsterdam — New York — Oxford

© 1989 Elsevier Science Publishers B.V. (Biomedical Division)

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior written permission of the publisher, Elsevier Science Publishers B.V., Biomedical Division, P.O. Box 1527, 1000 BM Amsterdam, The Netherlands.

No responsibility is assumed by the Publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein. Because of rapid advances in the medical sciences, the Publisher recommends that independent verification of diagnoses and drug dosages should be made.

Special regulations for readers in the USA - This publication has been registered with the Copyright Clearance Center Inc. (CCC), 27 Congress Street, Salem, MA 01970, USA. Information can be obtained from the CCC about conditions under which photocopies of parts of this publication may be made in the USA. All other copyright questions, including photocopying outside the USA, should be referred to the copyright owner, Elsevier Science Publishers B.V., unless otherwise specified.

International Congress Series No. 850
ISBN 0 444 81092 7

This book is printed on acid-free paper.

Published by:

Elsevier Science Publishers B.V.
(Biomedical Division)
P.O. Box 211
1000 AE Amsterdam
The Netherlands

Sole distributors for the USA and Canada:

Elsevier Science Publishing Company Inc.
655 Avenue of the Americas
New York, NY 10010
USA

Library of Congress Cataloging in Publication Data:

International Congress of Laser in Dentistry (1st : 1988 : Tokyo, Japan)

Lasers in dentistry : proceedings of the International Congress of Laser in Dentistry, Tokyo, Japan, 5-6 August 1988 / editors, Hajime Yamamoto, Kazuhiko Atsumi, Haruka Kusakari ; associate editors, Michio Shimakura, Teruo Kayano.

p. cm. -- (International congress series ; no. 850)

Includes bibliographies and index.

ISBN 0-444-81092-7 (U.S.)

1. Lasers in dentistry--Congresses. I. Yamamoto, Hajime.
II. Atsumi, Kazuhiko, 1928- III. Kusakari, Haruka. IV. Title.
V. Series.

[DNLM: 1. Lasers--therapeutic use--congresses. 2. Tooth Diseases--therapy--congresses. W3 EX89 no. 850 / WU 140 I617 1988L]

RK685.L37I58 1988

617.6--dc20

DNLM/DLC

for Library of Congress

89-7841
CIP

PREFACE

After the oscillation of the ruby laser beam by T.H. Maiman in 1960, it took only a quarter of a century before lasers became the multidisciplinary and multispecial tool in clinical medicine. At present, lasers are extensively applied in ophthalmology, surgery, and other clinical departments of medicine. Lasers are also utilized widely for various kinds of medical examinations, diagnosis, information processing and rehabilitation, and their application areas are expanding rapidly. In the field of dentistry, the use of the laser as a replacement for the dental drill was the first idea, however, the first successful application of laser in dentistry was the prevention of dental caries by means of laser irradiation. After the fruitful success of the 4th Congress of the International Society for Laser Surgery, LASER TOKYO '81, clinical application of lasers in dentistry has been promoted more and more in Japan. The Japan Society for Laser Medicine decided to organize the international congress focused on lasers in dentistry. This Congress was the first attempt to bring world-wide specialists together to discuss and improve this new frontier of 'Laser Dentistry'. The Congress was co-sponsored by the Japanese Association for Dental Science, Japan Dental Association and Tokyo Dental Association.

The International Congress of Laser in Dentistry was held in Tokyo, Japan on August 5th and 6th, 1988, hosted by Professor Hajime Yamamoto. There were 400 participants, including 60 from 16 foreign countries. The main theme of the Congress was 'Application of laser to oral and maxillofacial region'. The scientific program consisted of 4 special lectures, 1 symposium, 3 workshops and 44 free papers. The special lectures were as follows; 'Past, present and future in laser medicine and surgery' by Dr. K. Atsumi (Japan), honorable president of the Congress and president of the Japan Society for Laser Medicine; 'More than 10 years CO₂ laser research and applications in dentistry: computerized analysis' by Dr. F. Melcer (France); 'Essentials of laser' by Dr. H. Inaba (Japan); 'Studies of low power laser therapy of pain' by Dr. K. Kamikawa (Japan). The 6 symposiasts presented the clinical experiences of laser therapy in many fields of dentistry under the theme of applications of lasers in dentistry.

Free papers were divided into 8 topics; Basic research (8 papers), Instrumentation (6 papers), Measurement and diagnosis (5 papers), Oral and maxillofacial surgery (11 papers), Dental caries and dental pulp (5 papers), Periodontology (3 papers), Analgesic effect (3 papers) and Treatment of malignant tumor (3 papers).

The symposium and free papers, disclosed clearly that lasers had many advantages in therapeutic and preventive dentistry in all fields of dentistry such as surgery, caries prevention and pain clinic; and also pointed out the necessity of basic research, especially about the biological effects of low power lasers.

This volume will include the most important papers of those presented in the Congress, and provide clinicians and researchers with the opportunity to learn much about the extensive, up-to-date information on several new therapeutic and diagnostic strategies in laser dentistry. The Congress and this book should be a stepping stone to the future development of laser dentistry and it is not too much to say that 'laser dentistry' is future dental science. We believe that laser dentistry will

enable us to pave the way for the diagnosis and treatment which could not be achieved by conventional methods.

During the Congress, delegates from the participating countries discussed the future of laser dentistry and decided to organize the congress periodically. The 2nd International Congress of Laser in Dentistry will be held in Paris in 1990. The Chairman will be Dr. J. Melcer, Professor of University Paris-V, and the tentative Secretary General, Professor H. Yamamoto. There was also a discussion about the inauguration of the International Association of Laser Dentistry. It is expected that many participants from all over the world will attend the 2nd Congress and contribute to the establishment of the International Association of Laser Dentistry.

Editor-in-Chief/Congress Chairman

Hajime Yamamoto, D.D.S., Ph.D.
Professor of Department of Oral Pathology
Tokyo Medical and Dental University

ORGANIZATION

Honorable President:

Kazuhiko Atsumi (President of the Japan Society for Laser Medicine,
University of Tokyo)

Honorary Guest:

Imao Sunada (Chairman of Japanese Association for Dental Science)

President:

Kinai Tomita (Higashi Nippon Gakuen University)

Chairman:

Hajime Yamamoto (Tokyo Medical and Dental University)

Secretary General:

Haruka Kusakari (Niigata University)

Organizing Committee:

Hideo Aoki (Kanagawa Dental College)
Masahiko Fukaya (Aichigakuin University)
Keiichi Furumoto (Nippon Dental University, Tokyo)
Hiroshi Horiuchi (Tohoku University)
Kikuo Kamiyama (Tohoku University)
Joji Kato (Nippon Dental University, Niigata)
Teruo Kayano (Tokyo Medical and Dental University)
Kokichi Matsumoto (Showa University)
Shigeru Matsuo (Fukuoka Dental College)
Ikuko Morio (Tokyo Medical and Dental University)
Toshio Morioka (Kyushu University)
Akinori Nagasawa (The Tokyo Metropolitan Hiroo General Hospital)
Yoshihiro Narita (Tokyo Medical College)
Toshio Nishiyama (Nippon Dental University, Niigata)
Tanekuni Nomoto (Keio University)
Yasushi Ohashi (Niigata University)
Masatoshi Ohnishi (Yamanashi Medical School)
Michio Shimakura (Niigata University)
Shigetoshi Shioda (Tokyo Medical and Dental University)
Yoichi Uchiyama (Hokkaido University)

Advisory Members:

Shoji Enomoto (Tokyo Medical and Dental University)
Susumu Hayashi (Professor Emeritus of Tohoku University)
Fumio Inaba (Tohoku University)

Tetsuzo Inoue (National Defence Medical College)
Kanji Ishibashi (Iwate Medical University)
Isao Ishikawa (Tokyo Medical and Dental University)
Kiyoo Kamikawa (Meiji College of Oriental Medicine)
Uichi Kubo (Kinki University)
Takayuki Kuroda (Tokyo Medical and Dental University)
Narong Nimsakul (The Japan Society for Laser Medicine)
Tsuyoshi Nishisaka (Tokyo University of Agriculture and Technology)
Yanao Oguro (National Cancer Center)
Mitsuhiro Osada (Tokai University)
Toshio Oshiro (Japan Medical Laser Laboratory)
Takashi Oyama (Tokyo Medical and Dental University)
Hisao Tajiri (National Cancer Center)
Toshiaki Takizawa (Medical Center of East Japan Railway Company)

CONTENTS

LECTURES

Current status and future of laser surgery and medicine in Japan <i>K. Atsumi</i>	3
More than ten years of CO ₂ laser research and applications: Computerised analysis <i>F. Melcer</i>	15
Essentials of laser <i>H. Inaba</i>	25
Studies on low power laser therapy of pain <i>K. Kamikawa</i>	29

SYMPOSIUM

More than ten years of CO ₂ laser research and clinical applications in dentistry: Clinical results <i>J. Melcer</i>	41
Wound healing after carbon dioxide laser surgery in the oral cavity <i>S.E. Fisher and J.W. Frame</i>	47
Application of Nd-YAG laser and fluoride in the prevention of dental caries <i>T. Morioka, S. Tagomori and Y. Nara</i>	55
Clinical application of various lasers in oral surgery <i>K. Hashimoto</i>	63
Laser diagnosis and treatment for precancerous lesion <i>Ma Baozhang and Xu Wong</i>	71
Technical development in application of lasers to dentistry <i>A. Nagasawa</i>	73

BASIC RESEARCH

Effects of low power He-Ne laser on the healing of full-thickness skin defects <i>S. Ikeuchi, F. Ohsaka, S. Asanami and T. Nomoto</i>	85
Wound healing process following cryosurgery and Nd-YAG laser therapy of the oral mucosa in rabbits <i>R. Schmelzeisen, F. Blecker, G. Stauch, St. Hessel and K. Pohlmeier</i>	91
Effects of excimer laser irradiation on bone <i>K. Sato, Y. Kohsaka, S. Fujisaka, S. Ochiai and H. Yamamoto</i>	99
Effects of Al-Ga-As laser in bone histomorphometry <i>N. Orikasa, M. Shimakura and H. Kusakari</i>	105
In vitro study of the melanin depigmentation by irradiation with argon ion laser <i>J. Suzuki, T. Kayano and H. Yamamoto</i>	111

INSTRUMENTATION

- Clinical use of the lasersat CO₂ waveguide laser: Requirements and practical use
C. Severin 119
- Introduction of new dental oral YAG laser handpiece and its clinical application
K. Yoshida, K. Kakami, A. Ito, M. Kaneko, A. Ishihara, H. Kato and M. Fukaya 125
- The applications of Nd:YAG laser for low energy laser therapy in the intraoral region
M. Kaneko, K. Kakami, K. Yoshida, A. Ito, M. Kato, H. Kato, A. Ishihara and M. Fukaya 131
- Excimer lasers: Basic physics and possible applications in dental surgery
J. Koort and M. Frentzen 137
- Technical development in application of lasers to dentistry - development of appliances and systems
A. Nagasawa and K. Kato 143

MEASUREMENT AND DIAGNOSIS

- Creation of multiplex hologram through synthesis of CT images
T. Katsuki and M. Goto 151
- Laser Doppler flowmetry applied to blood flow in oral mucosa
Y. Kato, T. Kuroda, T. Tamura and T. Togawa 157
- Measurement of flap blood flow by laser Doppler flowmetry
M. Goto, K. Ishikawa and T. Katsuki 163
- Laser in the diagnosis of the TMJ problems
Y. Hatano 169

ORAL AND MAXILLOFACIAL SURGERY

- The use of CO₂ laser in oral and maxillofacial surgery
J. Lustmann, B. Azaz and J. Lewin-Epstein 175
- The CO₂ laser in oral surgery and periodontics
S. Barak and I. Kaplan 181
- Clinical experience of the CO₂ laser in the lesions of the tongue
K. Mori, H. Hamakawa and H. Tanioka 187
- Application of CO₂ laser to oral lesions and immunological study of oral lichen planus
M. Oka, E. Santoh, T. Harada and Y. Yoshimura 193
- The advantages of the CO₂ laser in the treatment of oral cavity hemangiomas
L. Gáspár and G. Szabó 199

Initial experience with CO ₂ laser for minor and major oral surgery <i>Loh Hong-Sai</i>	203
The present state of CO ₂ and Nd-YAG laser therapy in our clinic <i>K. Iijima, H. Shiba, S. Asanami and T. Nomoto</i>	209
Treatment of mucocele using Nd-YAG laser <i>K. Yoshitake, T. Matsumoto and H. Kobayashi</i>	215
Sialolithotomies with CO ₂ laser <i>B. Azaz, R. Zeltser and Y. Lustmann</i>	221

DENTAL CARIES AND DENTAL PULP

Effect of Nd:YAG laser irradiation just after the application of 2% NaF solution on experimental dental caries of rats <i>K. Shinada, S. Okada and H. Yamamoto</i>	229
Caries removal and conditioning of tooth surfaces for adhesive filling techniques by using 193 nm - excimer laser - preliminary results <i>M. Frentzen, H.J. Koort, O. Kermani and U.M. Dardenne</i>	235
Argon ion laser beam as composite resin light curing agent <i>C. Severin and M. Maquin</i>	241
In vitro study of the effect of lasers irradiation on streptococcus mutans <i>S. Ochiai, Y. Yamada and M. Takagi</i>	247
Histopathological changes of dental pulp after irradiation by argon, carbon-dioxide or Nd:YAG laser in rats <i>S. Shoji and H. Horiuchi</i>	253

PERIODONTOLOGY

The use of CO ₂ laser beam in periodontology <i>J. Melcer</i>	261
---	-----

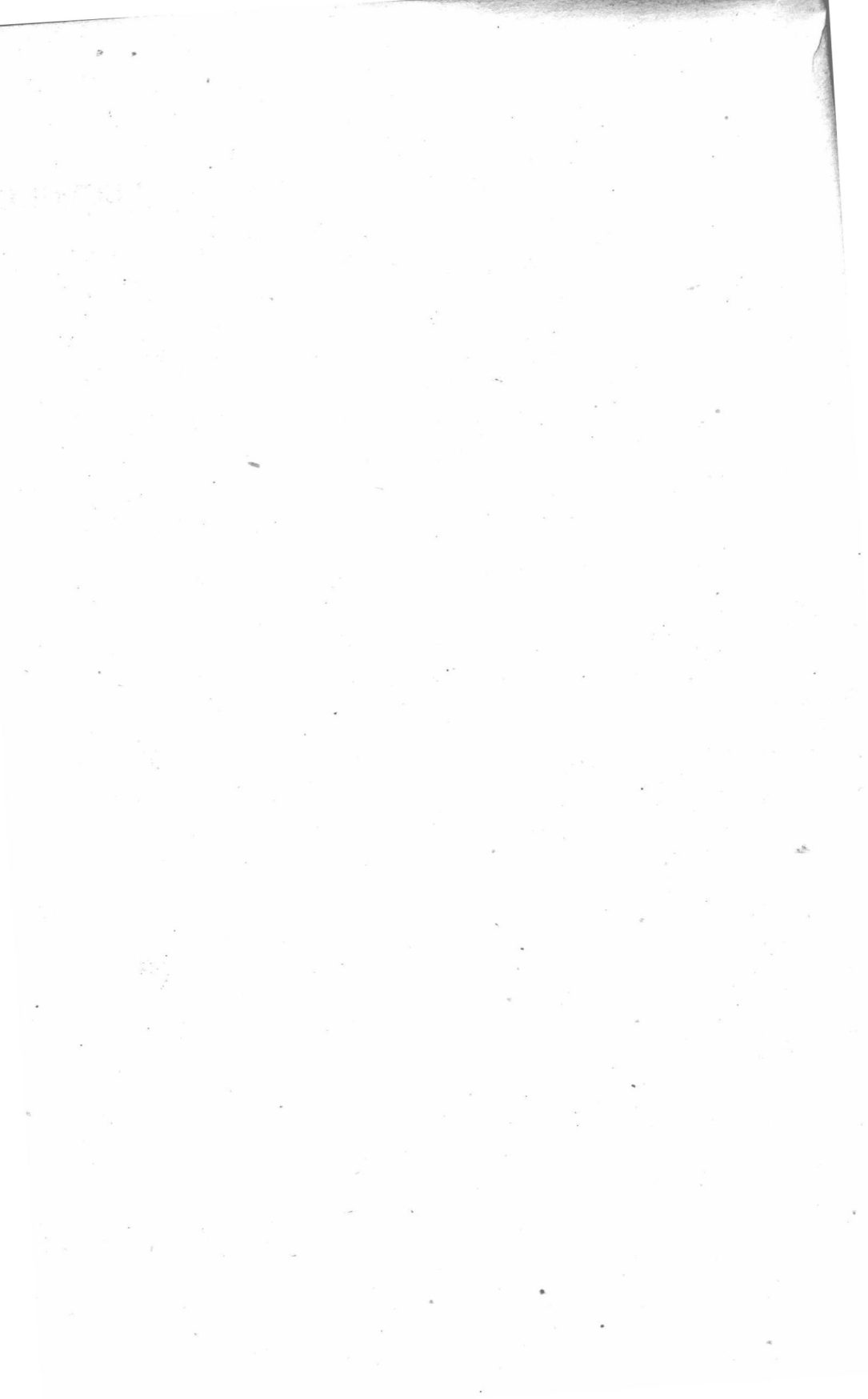
ANALGESIC EFFECT

Analgesic effect of soft laser irradiation on the heat nociceptors in the cat tongue <i>S. Mezawa and T. Saito</i>	267
Studies of Nd:YAG low power laser irradiation on stellate ganglion <i>A. Ito, K. Kakami, K. Yoshida, M. Kato, A. Ishihara, M. Kaneko and M. Fukaya</i>	271
A study of the analgesic effect of low power He-Ne laser and its mechanism by electrophysiological means <i>Guang Hua Wang, Shu Jun Jiang, San Jue Hu, Guan Cheng Zheng and Shi Yun Peng</i>	277

TREATMENT OF MALIGNANT TUMOR

Application of CO ₂ laser in treatment of carcinoma of the tongue <i>T. Nishimura and Shin-Ichi Kita</i>	285
Studies on Nd:YAG laserthermia for the oral region <i>Y. Watanabe, K. Takeuchi, H. Tsunekawa, T. Toyoda, T. Kawai, Y. Kameyama and N. Daikuzono</i>	287
An experimental study of the photodynamic therapy for oral cancer <i>I. Yamada, K. Hasimoto, K. Nakano, K.J. Hsieh, K. Tomitsuka, T. Miyamoto, T. Yanagawa and S. Shioda</i>	295
Author Index	301

LECTURES



CURRENT STATUS AND FUTURE OF LASER SURGERY AND MEDICINE IN JAPAN

KAZUHIKO ATSUMI

Institute of Medical Electronics, Faculty of Medicine, University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo, 113 (JAPAN)

INTRODUCTION

Japanese research on laser surgery and medicine was started in 1965 to study irradiation effect on tissues and tumors of mice by ruby laser by author in University of Tokyo.

In 1966, high power ruby laser unit for medical use was constructed and applied for the first clinical case of skin cancer in University of Tokyo in 1967.

In 1968, high power CO₂ laser unit was constructed and basic studies were done. In 1969, CO₂ laser was used in neurosurgery by Dr. Takizawa.

In 1973, CO₂ laser was applied in ENT by Dr. Mihashi. Argon and ruby lasers were used in plastic surgery by Dr. Ohmori.

In 1974, the Q-switch of Nd-YAG laser was applied for dental caries prevention by Dr. Yamamoto.

In 1975, CO₂ laser unit was used in oral surgery by Dr. Nagasawa.

In 1977, the first Japanese Meeting of Laser Medicine was organized and 50 medical doctors and engineers joined in this meeting.

In 1979, the first YAG laser endoscopy treatment for gastrointestinal bleeding was performed by Dr. Mito.

In 1980, laser acupuncture was done by Dr. Ohnishi.

In 1980, the Japanese Society of Laser Surgery and Medicine was organized and the first conference was carried out. 300 medical doctors and engineers joined in this conference.

In 1981, photodynamic therapy for lung cancer was started by Dr. Hayata.

In 1985, a new laser hospital was constructed at Omiya 20 miles north of Tokyo. In this hospital, YAG, argon and argon dye laser units are centralized and the laser powers are transmitted to the operations rooms and outpatients rooms through the optical fiber. Laser selection, power, safety, appointment are controlled by computer.

In 1987, the number of members of Japanese Society for Laser Surgery and Medicine counted over 1,000. The major parts of the specialities are surgery, endoscopy, oral and dental, ENT and plastic surgery. (Table(1))

TABLE 1

HISTORY OF LASER SURGERY IN JAPAN

- 1965 Ruby Laser (2-7 Joules) Radiation Effects on Tissues and Tumors of Mice (K. Atsumi, et al.)
- 1966 High Power Ruby Laser Unit (50 Joules) for Medical Use (K. Atsumi, et al.)
- 1967 The 1st Clinical Case - skin cancer - (Ruby) Laser Treatment (K. Hishimoto, K. Atsumi, et al.)
- 1967 Ruby Laser (4 Joules) Radiation Effects on Teeth (H. Yamamoto, et al.)
- 1968 High Power CO₂ Laser (50 Watts) Unit and its Biological Effects (K. Atsumi, et al.)
- 1968 He-Ne Laser (10 mW) Radiation Effects on Brain Tissues and Tumors of Mice (K. Kamikawa, et al.)
- 1969 CO₂ Laser (35 W) in Neurosurgery (T. Takizawa)
- 1970 Argon Laser (1 W) Radiation Effects on Brain Tissues and Tumors of Mice
(K. Kamikawa, et al.)
- 1973 CO₂ Laser (38 W) in Otolaryngology (S. Mihashi, et al.)
- 1974 Nd-YAG Laser (50 W) in Neurosurgery (K. Kamikawa, et al.)
- 1974 Nd-YAG (Q-switch) Laser for Dental Caries Prevention (H. Yamamoto)
- 1975 Argon Laser in Plastic Surgery (S. Ohmori)
- 1975 CO₂ Laser (50 W) in Oral Surgery (A. Nagasawa)
- 1975 Ruby Laser (160 Joules) in Plastic Surgery (T. Ohshiro)
- 1977 CO₂ Laser (50 W) in Plastic Surgery (Narong Nimsakul)
- 1977 The 1st Japanese Meeting of Laser Medicine (November, Tokyo)
- 1978 CO₂ Laser (100 W) Surgical Unit for Medical Use (K. Atsumi, et al.)
- 1979 Nd-YAG Laser Endoscopy Treatment for Gastrointestinal Bleeding (M. Mito, et al.)
- 1980 Laser Acupuncture (Ohnishi)
- 1980 Nd-YAG Laser Endoscopy Treatment for Stomach Cancer (K. Mizushima)
- 1980 The 1st Conference on Japanese Society of Laser Surgery and Medicine
(November, Tokyo, Presided by Dr. M. Osada)
- 1981 Laser Photoradiation Therapy for Lung Cancer (Y. Hayata)
- 1981 Laser Spectro Analysis for Cancer Diagnosis (T. Sakita)
- 1982 CO Laser Surgical Unit (M. Kikuchi)
- 1982 Laser Pain Therapy (K. Kamikawa)
- 1982 Laser Micro-Vascular Anastomosis (N. Hayashi)
- 1983 HpD-Laser Photoradiation Therapy by N₂-Dye Laser (K. Ida)
- 1983 Laser Pain Therapy -Diode Laser- (T. Oshiro)
- 1984 Photodynamic Therapy by Gold Vapor Laser (H. Kuzumi)
- 1984 Medical Application of Excimer Laser (K. Aizawa)
- 1984 Laser Cholelithotripsy through Bile Duct (T. Kozu)

TABLE 1

HISTORY OF LASER SURGERY IN JAPAN (continued)

- 1985 : PDT by Use of Pheophoride Irradiated by Nd-YAG Laser (S. Mashiko, H. Inaba)
- : Laser Reactive New Metal Complex (Platinum Blue Fluorescein Sodium Complex) for Brain Tumor Therapy (N. Hayashi)
 - : Percutaneous Trans-hepatic Laser Vaporization (Q. Hashimoto)
 - : Nd-YAG Laser Application to Hyperthermia (T. Nobori)
 - : Percutaneous Laser Angioplasty for Peripheral (Femoral) Artery (S. Takekawa)
 - : Biostimulation on Chronic Rheumatoid Arthritis by He-Ne Laser (Y. Oyamada)
 - : Ruby and Argon Laser Unit with Kaleidoscanner (K. Iwasaki)
 - : Combined Laser Power Delivery of CO and Nd-YAG Laser by IR Glass Fiber (T. Arai)
 - : Flexible Hollow Light Guide (Aluminum & Teflon) for High Power CO₂ Laser (U. Kobo)
 - : New Centralized Laser Hospital
- 1986 : Introduction of Foreign DNA into Cultured Cells by Nd-YAG Laser (S. Kurata)
- : Endoscopic Laser Treatment of Gastric Cancer by a Newly Devised Cylindrical Metallic Probe (H. Kagei, et al.)
 - : PDT with Eosin Yellow by Argon Laser (S. Shibuya, et al.)
 - : Computerized Laser Microscanner in Plastic Surgery (N. Nimsakul)
 - : Nd-YAG Laser Irradiation for Hepatic Tumors under the Laparoscope (T. Katamoto, et al.)
 - : Laser Angioplasty with Nd-YAG Laser and Vascular Endoscopy (S. Takekawa)
 - : CO Laser Unit for Angioplasty (T. Arai, et al.)
 - : Clinical Vascular Anastomosis by CO₂ Low Power Laser (M. Okada)
 - : Myocardial Revascularization by Laser (M. Okada)
 - : Automatically Tracing Laser Irradiation System for Moving Target (A. Nagasawa)
- 1987 : Development of Laser Balloon through Intraportal Vein (Y. Shimamura)
- : Laser Iridotomy by Dye Laser (R. Ohki)
 - : Intradiscal Laser Nucleotomy (T. Yonezawa)
 - : Percutaneous Laser Nephrolithotomy (Y. Tanahashi)
 - : Laserlithotripsy by CO Laser (Y. Ohmichi)
 - : Nephrolithotripsy by Pulsed Dye Laser (I. Numata)
 - : Photosensitizer for PDT
 - 1) Mono-L-Seryl Chlorin e6 (Y. Yasunaka)
 - 2) Chloroaluminum Tetrasulphonated Phthalocyanine (K. Kunimi)
 - 3) Zinc Tetrasulphonated Phthalocyanine (T. Nishisaka)
 - 4) Tetracycline (T. Nishisaka)

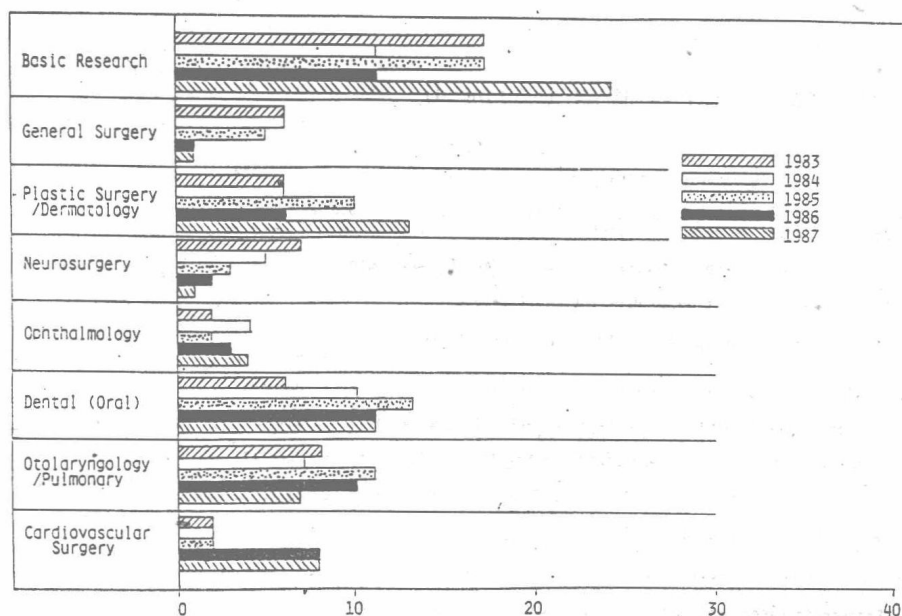


Fig. 1. Classification of the applied medical fields from the reported papers in the annual meeting of Japan Society for Laser Surgery & Medicine. No.1 (1983 - 1987)

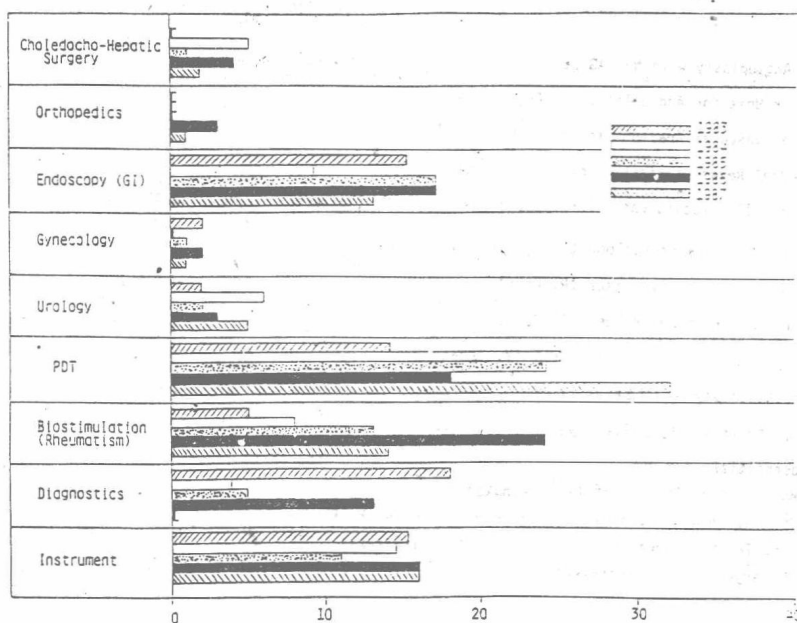


Fig. 2. Classification of the applied medical fields from the reported papers in the annual meeting of Japan Society for Laser Surgery & Medicine. No.2 (1983 - 1987)

THE PRESENT STATE OF LASER SURGERY AND MEDICINE

The Figures(1)(2) show the classification of the applied medical fields from the reported papers in the annual meetings of Japanese society during five years from 1983 to 1987.

In the Figures(1)(2), basic research is large number and dental, plastic surgery and ENT are fairly large. Cardiovascular surgery has been increasing recently. The biggest number is PDT and endoscope, biostimulation and instrument are followed.

At the present state, the clinical fields can be classified according to the maturity as shown in the Figure(3). In the Figure(3), from upside to down, the matured fields to the prematured fields are arranged. Basic research of oncology, orthopedics, dental, cardiovascular fields are the prematured areas.

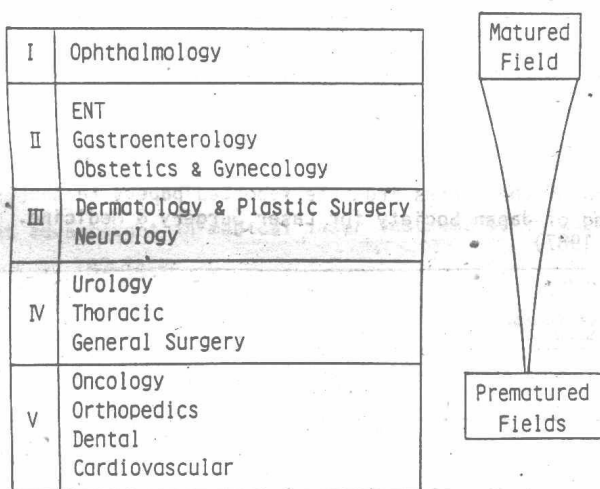


Fig. 3. Maturity of laser surgery.

The Figures(4)(5) show the lasers from the reported papers in Japanese society meetings. In the Figures(4)(5), Nd-YAG laser is the largest number and is increasing recently. CO₂ laser follows and diode laser shows fairly large. Argon dye is large number because of PDT application.

The Table(2) shows laser surgical units installed in the Japanese hospitals in 1986. 230 CO₂ lasers, 170 Nd-YAG lasers and 30 argon lasers were counted. Medical statistics of Japan are indicated as the references.