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Comparative Study of Wound Healing in Porcine Uterus with CO_2 Laser and Scalpel Incisions

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Abstract : This study compared the instrument performance and tissue healing of a steel scalpel with a CO_2 laser in an animal uterine surgery model. Five Landrace and Yorkshire mixed breed pigs were used. Two symmetrical incisions were made in the uterine of each pig. One incision was made on the left side of the uterine horn using a steel scalpel, while the other incision was performed on the right side using a CO_2 laser with an 8W output power. Each instrument was evaluated clinically for speed, ease of incision, and extent of bleeding. An ovariohysterectomy was performed at 21 days after the surgical procedure for a histological examination. The scalpel was an easier instrument to use in the confines of the uterine tissue, compared with the laser. However, there is no significant difference between the two groups. The amount of bleeding was less in the laser group but the time of the incisions was shorter with the scalpel. Postoperative uterus adhesion in the CO_2 laser incisions was lower than the scalpel incisions. Scalpel incisions showed complete restoration of the epithelium and endometrial gland. On the other hand, the laser incisions showed incomplete restoration of the epithelium and endometrial gland. Although the scalpel produced less damage to the uterine tissue and was easier to handle than the CO_2 laser, it did not provide hemostasis that was helpful for use on highly vascular tissue. The CO_2 laser provided good hemostasis but delayed wound healing.

Key words **:** CO_2 laser, pig, scalpel, uterine, wound healing.

Introduction

The steel scalpel is the most widely utilized tool in soft-tissue surgical procedures. The scalpel has many advantages, including ease of use, accuracy, and minimal damage to the adjacent tissue. However, scalpels do not provide a good hemostasis. Bleeding induced by a scalpel can obstruct the surgical field and sometimes result in excessive blood loss. Instruments that coagulate as they incise, such as electrosurgery, heated scalpel and a carbon dioxide (CO_2) laser, have been developed. The CO_2 laser is the most commonly used laser in soft tissue surgery. It emits a beam with a wavelength of 10.6 μm in the medium portion of the electromagnetic infrared spectrum, which is easily absorbed by tissue with a high water contact (2). In the early 1970s, the removal of nodules from the vocal cord of a dog demonstrated the surgical precision of the CO_2 laser (6), the CO_2 laser is commonly used in veterinary surgical procedures. However, there are no reports of evaluations of the CO_2 laser on uterine tissue.

The major advantages of the CO_2 laser are the production of local hemostasis, bacterial elimination and contact-free incision (1,11). However, the CO_2 laser can cause a delay in wound healing compared to scalpel incisions (4). Although there have been tissue studies comparing the scalpel with laser (4,8), there are no reports of a histological comparison of the effects of the scalpel and CO_2 laser on pig uterus tissue.

The aim of this study was to compare, through a histological examination, the quality of uterus tissue repair in pigs after an incision with a conventional scalpel versus a CO_2 laser.

Materials and Methods

Laser devices

In the present study, a continuous mode CO_2 laser (Ultra Dream Pulse, DSE Co. LTD, Seoul, Korea) emitting at 10.6 μm wavelength was used. Laser radiation was employed on the uterus tissue of pig using a CO_2 laser with a 2 mm spot size, 8W continuous wave. The delivery system consisted of a fiber-optic tube terminating in a hand piece with a tip of 0.4 mm in diameter and 50 mm in length. The laser tip was placed approximately 0.9 cm from the tissue surface during laser exposure (for approximately 4 seconds).

Experimental animals

This study was undertaken with five Landrace and Yorkshire mixed breed pigs (47-50 kg, 4-6 months old, female). All pigs were obtained from the experimental livestock farm of the

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College of Agriculture, Chungnam National University (CNU). The experimental and housing protocols were approved by the CNU Animal Care and Use Committee.

Premedication and anesthesia

The animals were premedicated with atropine sulfate (Atropine Sulfate®, Huons Co., LTD., 0.04 mg/kg, IM) and xlyazine (Rompun®, Bayer Korea LTD., Korea, 4.4 mg/kg IM) followed by tiletamine/zolazepam (Zoletil®, Virbac Labratories, France, 6.6 mg/kg IM) for anesthesia. Prophylactic antibiotics, ampicillin sodium (Penbrrok®, Chong Kun Dang Co., 20 mg/kg IV) and analgesic agent, meloxicam (Metacam®, Boehringer Ingelheim Co., 0.2 mg/kg IV) were administered before the surgical operation.

Surgical procedure

A laparotomy was performed using a midline incision. Two symmetrical incisions (approximately 10-15 mm in length) were made in the uterine of each pig. One incision was made on the left side of the uterine horn using a steel scalpel (Bard-Parker number 10; control side, Fig 1B & 1C), while the other incision was made on the right side using a CO_2 laser (test side, Fig 1A). The incisions of both sides were then sutured (Maxon 3-0, tyco/healthcare, Fig 1D), and the abdominal cavity was closed routinely.

Clinical and histological evaluations

Each instrument was evaluated clinically for ease of incision (scale of 0 to 4, with 4 representing the greatest ease), extent of bleeding (scale of 0 to 4, with 4 representing the greatest bleeding), and speed (in seconds), Three weeks later, all the animals were evaluated for postoperative adhesion (scale of 0 to 4, with 4 representing the greatest adhesion). An ovariohysterectomy was carried out at 21 days after the surgical procedure for a histological examination.

Statistical analysis

The results are expressed as the mean ± SD. The statistically significant differences between the groups were assessed using a two-tailed, paired Student's *t* test. A p value < 0.05 was considered significant.

Results

Instrument performance

Fig 2 shows the performance of the two instruments tests. The scalpel was an easier instrument to use in the confines of the uterine tissue than the laser. However, there was no significant difference between the two groups. The amount of bleeding was significant lower in the laser group than in the CO_2 groups ($p < 0.05$ compared with scalpel). The time of the incisions was significant longer with the laser ($p < 0.05$ compared with scalpel).

Postoperative adhesions and histology

The scores of adhesions were lower in the laser group, but there was no significant different (Fig 3). Fig 4 and 5 show representative micrographs of the healing incisions. Overall,

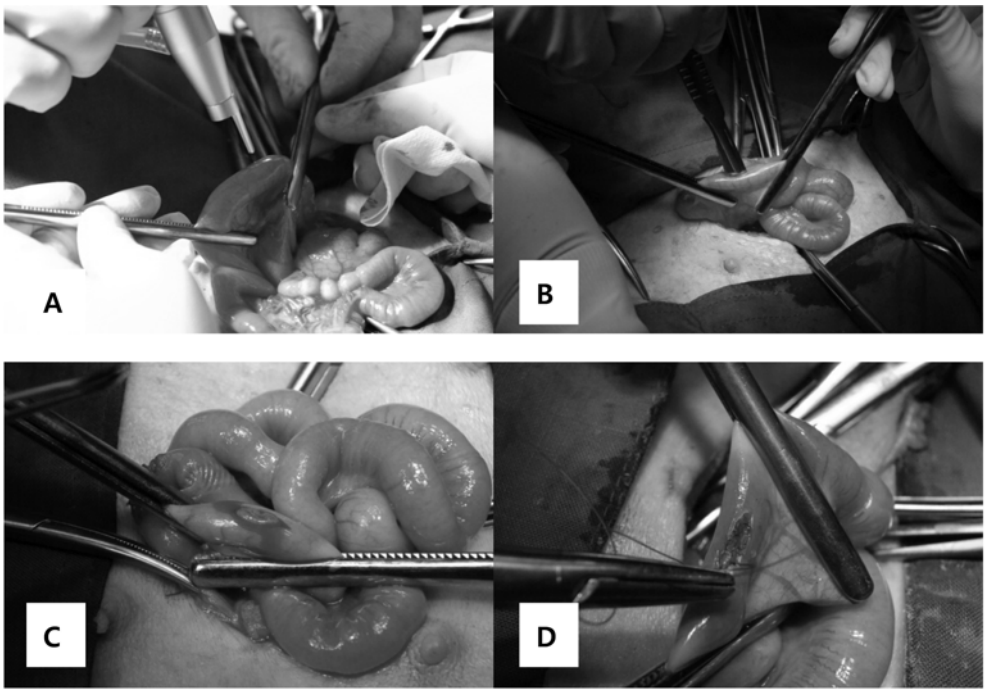

Fig 1. Surgical procedure. After air was forced through a hollow, laser incision (A) on the left horn and scalpel incision (B) on the right horn were performed. The amount of bleeding in the scalpel incision (C) appeared more than in the laser incision. The laser incisions were closed with sutures (D).

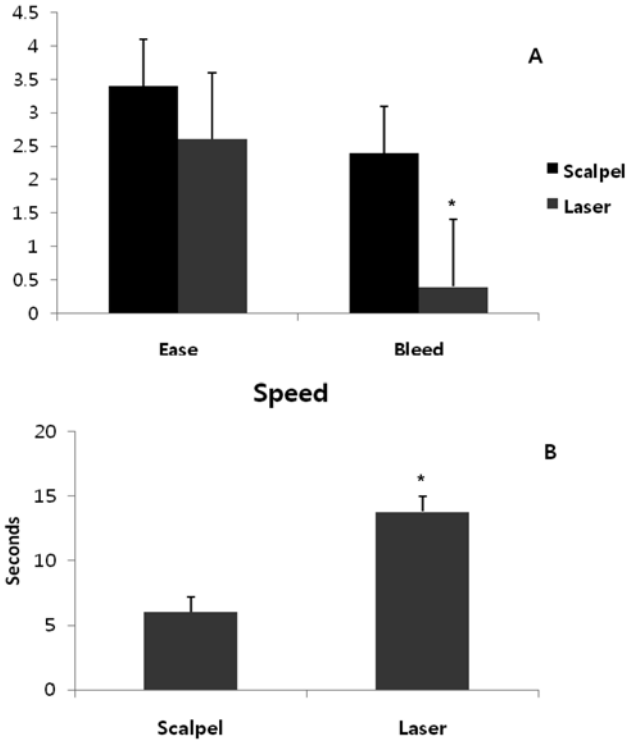

Fig 2. Graphic representations of the ease of instrument use (scale of 0 to 4) A, and degree of bleeding (scale of 0 to 4) A, between the instrument groups for incisions. The speed of the incisions (in seconds) are shown in B.
*Significantly different ($P < 0.05$) from scalpel.

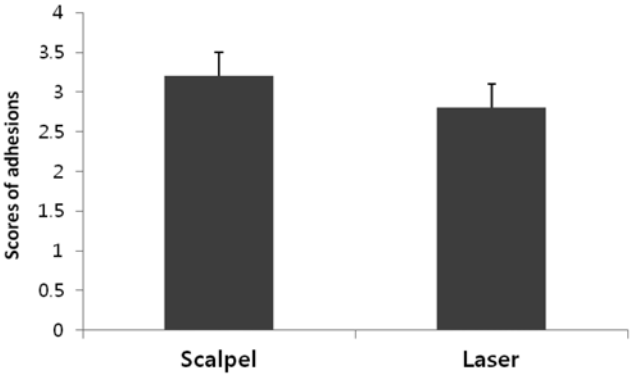

Fig 3. The scores of adhesions (day 21) of the uterine horns in a scalpel group and laser group.

the differences in wound healing were apparent at day 21. The scalpel incisions showed complete restoration of the epithelium and endometrial gland, no inflammatory cell reactions, and no thermal injury to the surrounding tissue. The formation of circular myometrium in the muscle layer was observed but there was no longitudinal myometrium was observed (Fig 4). The laser incisions showed incomplete restoration of the epithelium and endometrial gland. The continuity of the muscle layer was severely disrupted around the incision. The wound defect was not completely regenerated (Fig 5).

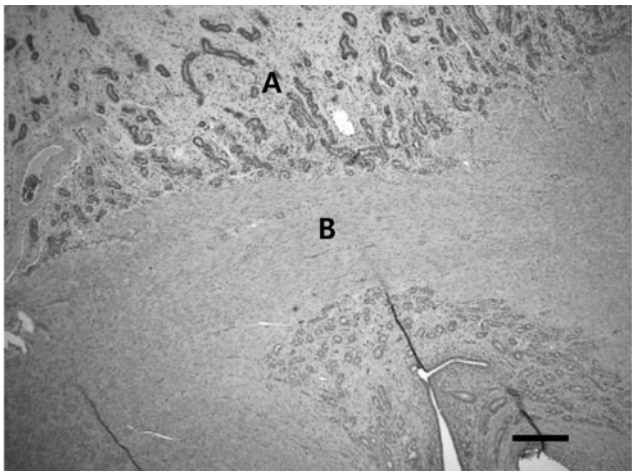

Fig 4. Microscopic examination of the scalpel specimens revealed normal mucosa when observed at day 21, with no evidence of gross bacterial contamination or deviance from the normal mucosal and muscle characteristics. Regeneration of the epithelium and endometrial gland was observed in the uterus mucosa (A). Formation of circular myometerium in the muscle layer was observed, but longitudinal myometerium was not observed (B). Bar = 10 μm.

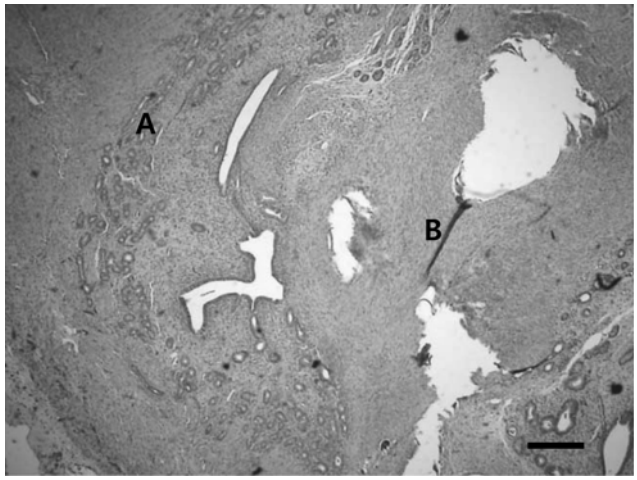

Fig 5. Microscopy examination of the CO_2 laser specimens revealed a uterus mucosa when observed at day 21, with little regeneration of the epithelium and endometrial gland (A). The continuity of the muscle layer was severely disrupted around the incision (B). The wound defect was not completely regenerated. Bar = 10 μm.

Discussion

The differences in healing between the surgical wounds produced by the scalpel and continuous wave mode of the CO_2 laser with an 8W power output were compared. The CO_2 laser has a wavelength of 10.6 μm and is absorbed by water, resulting in vaporization of the intracellular and extracellular fluid and the disintegration of cells (7). This action makes the CO_2 laser the best choice for general soft tissue surgery by producing the following benefit; ablation, hemostasis, decreased

post-operative pain, decreased swelling and quicker recovery. However, there have been many different opinions. The CO_2 laser is a reliable tool for a variety of surgical procedures, but it can cause excess thermal damage while cutting. Many studies have been carried out to reduce the level of thermal damage. The wavelength of the laser, power setting and exposure time are important parameters governing the extent of thermal injury to the tissue. In contrast, scalpel wounds do not cause any thermal damage but allow extravasation of the blood and lymph fluid, causing a larger inflammatory response with the resulting swelling and scab formation (5).

Earlier studies focused on the interactions of various surgical instruments on skin incisions. In this study, the extent of the tissue injury and the speed and the completeness of wound healing after surgical incisions in the uterine mucosa of swine using scalpel or CO_2 laser were compared. The differences in healing between the surgical wounds produced by the scalpel and CO_2 laser at 8W power output were compared at 21 days after the surgical procedure. The laser irradiation parameters were those recommended by the manufacturer and based on the literature. The energy density employed was in accordance with previous studies on animals (9).

These results suggest that scalpel excisions may be made more rapidly and easily. However, the scalpel produced significantly more bleeding than the CO_2 laser, which might obscure the surgical field for surgeons. In this study, the laser has some notable advantages. Not only does hemostatic cutting benefit the tissue, it provides a clear, dry surgical field for the surgeon. Adhesions were provoked in all animals that underwent surgery. However, postoperative uterus adhesion in the laser group was lower than the scalpel group.

When the CO_2 laser beam is focused, it incises the tissue in a manner similar to a sharp blade but with improved hemostasis (10). Despite this advantage, several studies in the past have reported impaired wound healing associated with the use of a CO_2 laser (3,10). Laser incisions demonstrated increased acute inflammation in areas corresponding to the zones of thermal damage. In addition, the delay in restoration of the epithelial barrier was dependent on the amount of acute thermally damaged tissue. In this study, the histological results were consistent with previous descriptions of healing laser incisions. Consequently, the laser group had a different histology from that of a scalpel incision, where no wound defect was present. Scalpel incisions showed complete restoration of the epithelium and endometrial gland. On the other hand, the laser incisions showed incomplete restoration of the epithelium and endometrial gland. Thermally denatured connective tissue presents a barrier to a reorganization of the wound site by newly formed granulation tissue. The delay in wound healing might be explained by an increased burden of necrotic tissue whose degradation requires the prolonged activation of inflammatory cells. It is also possible that the hemostasis of the laser induces local microvascular damage and reduces the number of inflammatory cells necessary for healing.

To our knowledge, this is the first study to compare the effect of wound healing after an incision with a CO_2 laser and a scalpel in a porcine uterus. Although the scalpel produced less damage to the uterine tissue and was easier to handle than the CO_2 laser, it did not provide hemostasis that helpful for use in highly vascular tissue. The CO_2 laser provided good hemostasis, but delayed wound healing. These results suggest that a decrease in the delay of wound healing might be due to the reduced laser radiation. Further studies will be needed to determine the most suitable output power of the CO_2 laser for preventing a delay in wound healing.

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CO_2 Laser와 Scalpel을 이용한 절개 시 돼지 자궁에서의 창상 치유 평가

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요 약 : Steel scalpel과 CO_2 laser를 이용한 돼지 자궁 절개 시 창상 치유에 미치는 영향을 평가하고자 본 실험을 실시하였다. 다섯 마리의 Landrace - Yorkshire 혼혈 종 돼지를 이용하였고, 각각의 돼지에서 좌측 및 우측의 자궁에 대칭적으로 scalpel 과 CO_2 laser를 이용하여 절개 하였다. 각각의 기구는 절개 속도, 절개의 용이성 및 출혈 정도를 평가 하였으며 수술 후 21일에 육안적인 유착 정도와 조직학적 검사를 실시하였다. Scalpel을 이용한 절개는 레이저를 이용한 절개보다 용이하였으나 두 군간의 유의성은 없었다. 레이저를 이용한 절개 시 출혈량은 적었으나 절개속도는 scalpel을 이용한 경우가 빨랐다. CO_2 laser 절개에서의 수술 후 자궁 유착은 scalpel 절개에서 보다 적게 발생하였다. 조직학적 검사에서 scalpel 절개의 경우 상피 조직과 자궁내막선의 재생이 완전히 이루어 졌으나 레이저를 이용한 경우 불완전한 재생 상태를 보였다. 비록 scalpel을 이용한 절개가 CO_2 laser를 이용한 경우 보다 조직 손상이 적었으며 사용하기 용이하였으나 출혈이 많은 단점이 있다. 반면 CO_2 laser를 이용한 절개의 경우 지혈 효과는 좋으나 창상 치유를 지연 시켰다.

주요어 : CO_2 레이저, scalpel, 자궁, 돼지, 창상 치유.