

Bipolar Versus Thulium-YAG Laser En Bloc Resection of Bladder Tumors: A Prospective Randomized Controlled Trial

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Abstract

Background

En bloc resection of bladder tumors (ERBT) has gained increasing acceptance as an alternative to conventional TURBT because it enables intact specimen retrieval while minimizing tissue fragmentation and thermal distortion. However, the optimal energy source for ERBT remains controversial. In this study the perioperative, pathological, and short-term oncological outcomes of bipolar versus thulium-YAG laser ERBT will be evaluated.

Methods

This prospective, randomized controlled trial included 140 patients with resectable bladder tumors (< 4 cm) treated between July 2023 and July 2025 at Menoufia University hospital. Patients were randomly assigned (1:1) to undergo en bloc resection using either bipolar energy or a thulium-YAG laser. The primary endpoint was perioperative hemoglobin drop. Secondary outcomes included intraoperative complications, hemostatic quality, detrusor muscle retrieval, histopathological thermal artifact, perioperative recovery, and 12-month recurrence. Histopathological assessment was performed by a blinded senior uropathologist, and all patients underwent standardized postoperative follow-up.

Results

Perioperative hemoglobin decline was comparable between the bipolar and thulium-YAG groups. Thulium-YAG ERBT was associated with significantly fewer intraoperative complications (1.4% vs. 20.0%, $p < 0.001$), better hemostatic quality, significantly lower histopathological thermal artifact, and a higher rate of detrusor muscle retrieval (94.3% vs. 67.1%, $p < 0.001$). Operative time, catheterization duration, postoperative pain scores, hospital stay, and 12-month recurrence rates were comparable between the two groups, although recurrence was numerically lower after thulium-YAG ERBT (7.1% vs. 12.9%, $p > 0.05$).

Conclusions

Both bipolar and thulium-YAG laser ERBT are safe and effective techniques for management of NMIBC. Nevertheless, thulium-YAG laser ERBT provided superior specimen quality, reduced histopathological thermal artifact, enhanced surgical precision, and improved intraoperative safety while maintaining comparable short-term oncological outcomes. Bipolar ERBT remains an effective alternative in centers where laser technology is unavailable.

Introduction

Bladder cancer is one of the most common urological malignancies. Approximately 75–80% of newly diagnosed cases are non-muscle-invasive bladder cancer (NMIBC), for which transurethral resection remains the cornerstone of diagnosis and treatment.

[1, 2]. Although several non-invasive diagnostic approaches have been developed, cystoscopy remains indispensable for the evaluation of patients with suspected bladder cancer, as urine cytology and other non-invasive modalities cannot consistently provide equivalent diagnostic accuracy[3]. Conventional wire loop TURBT continues to be the reference surgical approach for the management of NMIBC. Beyond complete endoscopic eradication of all visible lesions, the procedure is intended to provide representative tissue specimens that enable accurate histopathological diagnosis and staging[1]. En-bloc resection of bladder tumors (ERBT), initially described by Kawada et al. in 1997, has recently emerged as a promising alternative to conventional TURBT[4]. This approach facilitates en bloc excision of the entire tumor as a single intact specimen while preserving key oncological principles, including avoidance of tumor fragmentation and adherence to a no-touch surgical technique. In 2018, P.A. Geavlete and colleagues described bipolar en bloc resection using a mushroom loop and reported favorable perioperative outcomes, including enhanced procedural safety, lower perioperative morbidity, and faster postoperative recovery compared with conventional monopolar TURBT. However, no significant advantage was observed in oncological outcomes[5]. The thulium laser was first introduced into urological practice in 2005[6]. Advances in laser technology have promoted the use of the thulium laser for en bloc bladder tumor resection, as it enables precise tissue dissection while maintaining excellent intraoperative hemostasis[7].

Methods

This prospective comparative clinical trial was conducted between July 2023 and July 2025. The study included patients scheduled for diagnostic cystoscopy and endoscopic management of bladder tumors. The study protocol was approved by the local Ethics Committee of our university, under study ID 7/2023UROL27 before patient enrolment. In addition, the trial was prospectively registered at ClinicalTrials.gov under the identifier NCT06119724. Before being included in the study, each participant provided written informed consent. Sample size was calculated using G Power 3.1.9 based on the study by Kramer et al., assuming $\alpha=0.05$ and 80% power. Seventy patients were recruited per group after accounting for a 10% dropout rate.[5]

Study Population and Randomization: Inclusion criteria were: (i) bladder tumors measuring <4 cm on contrast enhanced (CT), (ii) resectable bladder tumors, and (iii) age <80 years.

Exclusion criteria included: (i) bladder tumors >4 cm, (ii) metastatic bladder cancer or radiologically apparent muscle invasive tumors, (iii) concomitant carcinoma in situ (CIS), (iv) patients with coagulopathies, and (v) bladder tumors arising within a diverticulum.

A total of 140 adult patients were enrolled and put into two study groups. A computer-generated random number sequence was used for randomization with a 1:1 allocation ratio, and allocation was concealed

using sequentially numbered, opaque, sealed envelopes. Outcome assessors and the senior uropathologist were blinded to treatment allocation. Group A included 70 patients treated with bipolar ERBT, while Group B included 70 patients treated with thulium-YAG laser ERBT.

Surgical Technique: All procedures were done by experienced surgeons in both bipolar and thulium ERBT techniques. All procedures were performed with the patient in the lithotomy position under either general or spinal anesthesia according to the patient's general condition and anesthetic assessment. Initial cystoscopic evaluation was performed to assess tumor number, size, location, morphology, tumor base, surrounding mucosa, and relation to the ureteric orifices. In the thulium laser group, ERBT was performed using a 26-F resectoscope (Karl Storz, Germany) with a 550- μ m end-firing PercuFib laser fiber (LISA Laser Products, Germany) connected to a Revolix Duo thulium laser generator. Laser settings were adjusted to continuous-wave cutting mode at 15 W power output. After circumferential marking of the lesion, dissection proceeded along the detrusor plane until complete en bloc excision was achieved. The continuous-wave thulium laser provided simultaneous cutting and coagulation, ensuring excellent hemostasis while preserving specimen integrity. For the bipolar arm, en bloc resection was carried out using a Karl Storz bipolar needle electrode connected to a Lamidey Noury OPTIMA electrosurgical generator. Initial power settings were 100 W for cutting and 80 W for coagulation, with intraoperative adjustments according to tissue response and hemostatic requirements. The same en bloc surgical principles adopted in the laser group were followed to achieve complete tumor excision while maintaining specimen integrity. All specimens were fixed in formalin and evaluated by a senior uropathologist for tumor stage, grade, muscularis propria involvement, and thermal artifact. Thermal artifact was assessed using predefined quantitative and qualitative grading systems as previously described by Balan et al.[8] The uropathologist was blinded to treatment allocation, as all specimens were submitted for histopathological evaluation without any information regarding the surgical technique or study group assignment. Postoperative care included bladder irrigation, catheter drainage, analgesia, antibiotics when indicated, and intravesical chemotherapy in selected patients. Follow-up was performed according to EAU guideline recommendations. The primary endpoint was perioperative hemoglobin drop. Secondary endpoints included detrusor muscle sampling, thermal artifact, obturator jerk, perioperative complications, and 1-year recurrence. All procedures were performed by three experienced surgeons. Each surgeon had previously completed more than 30 bipolar and 30 laser en bloc resection procedures prior to participation in the study, thereby minimizing the potential impact of the learning curve on surgical and oncological outcomes.

Statistical analysis: Of the 167 patients assessed for eligibility, 27 were excluded because they did not meet the inclusion criteria or declined participation. The remaining 140 patients were randomized equally between the two study groups. During follow-up, 11 patients were lost; however, all randomized patients were included in the final analysis according to the intention-to-treat principle (Figure 1). Statistical analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Categorical variables were compared using the Chi-square or Fisher's exact test, as appropriate. Continuous variables were assessed for normality using the Shapiro–Wilk test and compared using the independent-samples t-test or Mann–Whitney U test, according to data distribution. Within-group

comparisons were performed using the paired t-test for normally distributed variables. Statistical significance was defined as a two-sided p value < 0.05 .

Results

Baseline characteristics:

Baseline demographic, clinical, radiological, and cystoscopic characteristics were comparable between groups with no statistically significant difference as shown in (Table 1).

Perioperative outcomes:

Perioperative outcomes are summarized in Table 2. Thulium-YAG ERBT showed significantly fewer complications, better hemostasis, lower thermal artifact, and higher detrusor muscle retrieval, whereas operative time and hemoglobin decline were comparable between the two groups.

Oncological outcomes:

Oncological outcomes at 12 months were comparable between groups (Table 3)

Histopathological outcomes:

Regarding quality of specimen in pathological examination; there was statistically significant difference toward thulium laser group with mild tissue artifact with percent 97.1 % of cases in comparison to moderate and marked tissue artifact in bipolar group with 28.6% and 7.1% (p value < 0.001) as shown in examples in **figure 2&3&table 2**.

Discussion

In this prospective randomized comparative study; Thulium-YAG laser was associated with significantly less tissue charring and histopathological thermal artifact (97.1% mild in Thulium group vs. 35.7% moderate-to-severe in the bipolar group, $p < 0.001$), fewer intraoperative complications (1.4% vs. 20.1%, $p < 0.001$), and a higher rate of detrusor muscle presence in resected specimens (94.3% vs. 67.1%, $p < 0.001$), better hemostasis quality of Thulium YAG laser compared with Bipolar resection ($p=0.001$). These findings suggest a safer intraoperative profile for Thulium laser, while both techniques demonstrated comparable operative time, hospital stay, catheterization duration, and short-term recurrence rates at 1 year follow up cystoscopies. The current study adds to the growing body of evidence demonstrating the benefits of enbloc resection procedures of bladder tumors, especially laser-based techniques, for enhancing surgical quality and perioperative results. There are limited number of studies compared bipolar vs thulium enbloc resection of bladder tumors. The current results showed that the two study groups differed significantly in a number of clinical and pathological categories. In the current study, there was no statistically significant difference between the two groups across most baseline characteristics. Both groups experienced a nonsignificant postoperative reduction in

hemoglobin levels compared with baseline, also the magnitude of hemoglobin decline did not differ significantly between the two groups, indicating comparable perioperative blood loss; The mean Hb drop was slightly greater in the Bipolar group (0.46 ± 0.51 gm/dl) compared to Thulium YAG (0.36 ± 0.31 gm/dl); but this difference was **not** statistically significant ($p = 0.415$). This data supports the conclusion reached by Georgiana Xenia BĂLAN et al regarding bipolar group with HB drop 0.28 and agreed with the results of Zhonghua Xu et al and Zhang Li et al regarding thulium-Yag laser group.[8-11] Both groups had comparable operative durations; The Bipolar group had a mean of 30.81 ± 10.96 minutes, while the Thulium YAG group had a mean of 30.83 ± 9.09 minutes; The difference was not statistically significant ($p = 0.967$) this was similar to Hayashida et al, Li et al and Abotaleb et al with mean operative time 18.3 m/17.3m , 26.0 m/37.2m , 27.9m respectively as most of the studies in the literature operative time was around 30 minutes.[3, 11, 12] But in contrast to our finding Zhonghua Xu et al[11] found that. Thulium laser resection of bladder tumors was associated with a significantly shorter operation duration (25.96 ± 21.19 min vs 37.18 ± 25.77 min, $P = 0.018$). Comparable outcomes regarding complications were observed in the study by Deng-Xiong Li et al[13] and Osama Zaytoun et al[14] as The Thulium YAG group was nearly complication-free (98.6%), while the Bipolar group recorded complications in 20% of cases, including obturator jerk (14.2%), bladder perforation (2.9%), and controllable bleeding (2.9%). This difference was statistically significant ($p < 0.001$) confirming a significantly safer intraoperative profile of thulium compared to Bipolar resection, this finding may be partially explained by the predominance of lateral wall tumors in our cohort. Both groups showed predominantly clear irrigation fluid (87.1% vs. 94.3%), with no significant difference in hematuria rates ($p = 0.375$). Mean irrigation time was significantly shorter in the Thulium-YAG group, despite similar irrigation fluid color between both groups (4.70 ± 2.57 h vs. 3.99 ± 1.72 h), Regarding Hospital Stay and catheterization, both groups were discharged within one day. Catheterization duration was comparable (Bipolar: 3.96 ± 1.12 days vs. Thulium YAG: 3.67 ± 1.05 days; $p = 0.149$). In our study; The presence of detrusor muscle in the resected specimen was significantly more frequent in the Thulium-YAG group (94.3% vs. 67.1%; $p < 0.001$), reflecting superior resection quality of thulium laser; this corroborates the results published by Osama Zaytoun et al[14] as muscle presence in 95.2 % vs 64.7 % in bipolar group, Zhonghua Xu et al[11] showed similar results to the current study. Both groups were comparable regarding tumor grade (high grade: 67.1 % vs. 58.6 %; $p = 0.294$) and pathological stage showed a statistically non-significant difference that most likely reflects baseline variation rather than an effect of the surgical technique. (predominantly T1:bipolar 62.9% vs. Thulium Yag 50%; $p = 0.203$) ; these data supports the conclusion reached by Abotaleb et al , Hayashida et al and Liang et al as most of their tumors were T1[3, 12, 15], on contrast Cheng et al[16] and BĂLAN et al[8] found Ta tumors predominates with percent of 54% and 53% respectively; this may be attributed to aggressiveness of tumors in our group and large tumor size reflecting high risk patients. Thulium YAG was associated with significantly lower thermal artifact in pathological specimens as thulium group show mild artifact in 97.1 % of patients while bipolar group shows moderate and severe thermal artifact in 35.7% of patients ($p < 0.001$), this result was similar to those obtained by BĂLAN et al. [8] Tumor recurrence rates were comparable between the two groups (Bipolar: 12.9% vs. Thulium YAG: 7.1%). No statistically significant difference was found between the two groups in oncological outcomes ($p = 0.373$). this result was similar to those obtained by Cheng et

al[16] and Li et al[11]. These findings have several practical implications for urologists. First, for lateral wall tumors—where obturator jerk poses a significant risk—Thulium-YAG laser en bloc resection appears to be the safer option, virtually eliminating this complication (1.4% vs. 20% with bipolar). Second, the superior detrusor muscle detection rate with thulium laser (94.3% vs. 67.1%) may improve pathological staging accuracy, potentially guiding more appropriate adjuvant therapy. Third, the reduced histopathological thermal artifact with thulium laser preserves specimen architecture, facilitating more reliable pathological interpretation. However, the higher equipment cost and limited availability of thulium laser systems may restrict widespread adoption. For centers without laser access, bipolar en bloc resection remains a viable alternative, though surgeons should be aware of its higher complication rate (20%) and greater tissue artifact (35.7%). When using bipolar energy, particular caution is advised for lateral wall tumors, and alternative techniques (e.g., obturator nerve block, muscle relaxation) should be considered to mitigate obturator jerk risk. This study has several limitations. Although adequately powered for the primary perioperative endpoint, the sample size and 1-year follow-up limited the assessment of long-term oncological outcomes, including progression and cancer-specific survival. As a single-center study performed by experienced surgeons, the generalizability of the findings may be limited. Furthermore, exclusion of large or anatomically complex tumors restricts the applicability of the results to all patients with NMIBC. Larger multicenter studies with longer follow-up are warranted to validate these findings. The study was powered for perioperative outcomes (80% power to detect a 25% complication difference) but underpowered for recurrence comparisons. Furthermore, progression, and cancer-specific survival explaining why the numerically lower recurrence with Thulium (7.1% vs. 12.9%) was not significant. Finally, exclusion of tumors >4 cm, multiple lesions, and dome/anterior wall sites limit generalizability. Larger, multicenter trials with centralized review and extended follow-up are needed. Despite these limitations, the randomized design, balanced baseline characteristics, and comprehensive pathological assessment strengthen the validity of the present findings.

Conclusion

Both bipolar and thulium-YAG laser ERBT are safe and effective techniques for management of NMIBC. Nevertheless, thulium-YAG laser ERBT provided superior specimen quality, reduced histopathological thermal artifact, enhanced surgical precision, and improved intraoperative safety while maintaining comparable short-term oncological outcomes. Bipolar ERBT remains an effective alternative in centers where laser technology is unavailable.

Declarations

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Author Contribution

Osama Abdelgawad: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing. Eid Elsherif: Investigation, Surgical procedures, Supervision, Writing – review & editing. Mohamed Omar: Investigation, Surgical procedures, Supervision, Writing – review & editing. Baher Salman: Resources, Project administration, Supervision, Writing – review & editing. Corresponding author. Mahmoud Amer: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. All authors read and approved the final manuscript.

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Tables

Tables are available in the Supplementary Files section.

Figures

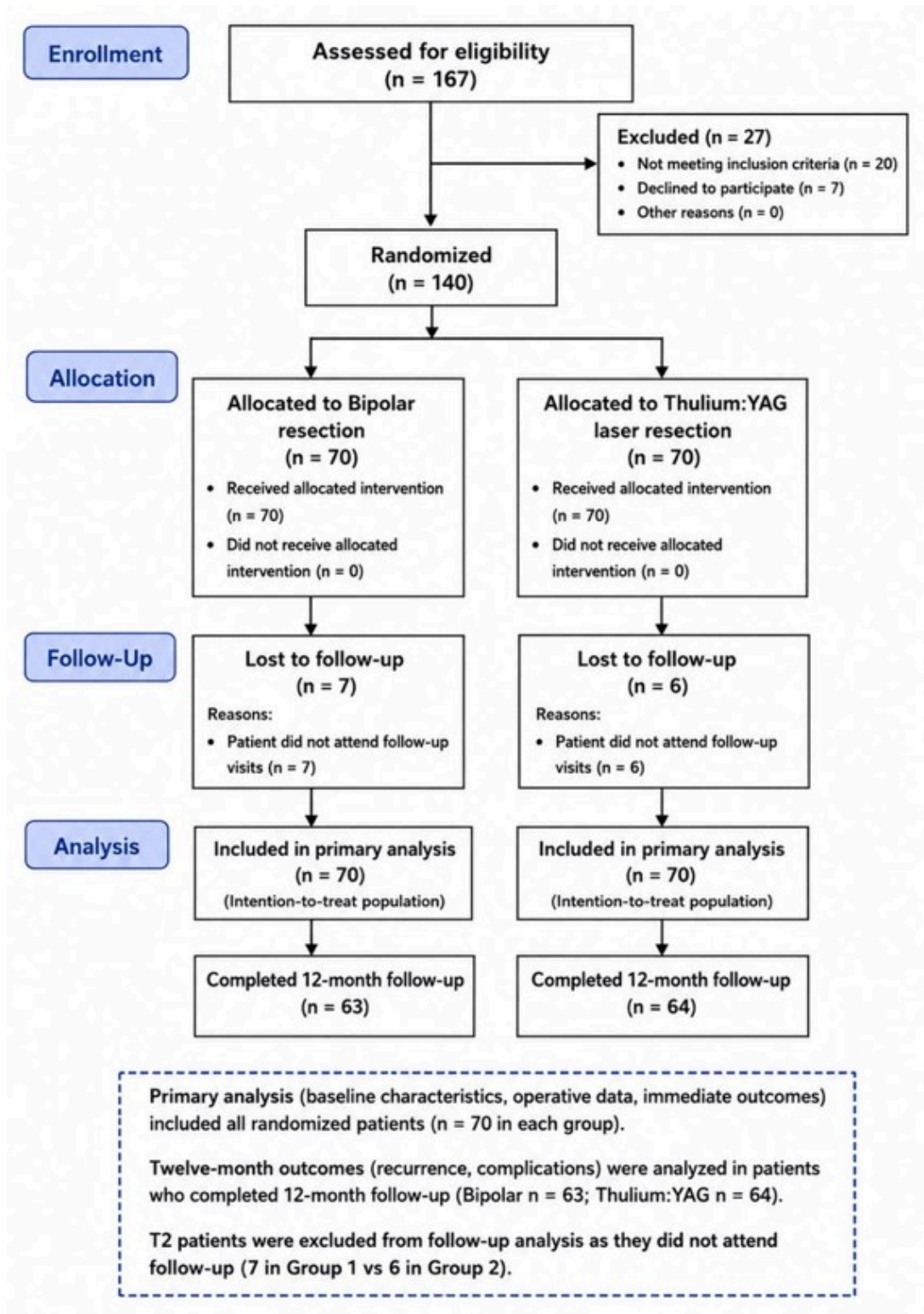


Figure 1

consort follow diagram

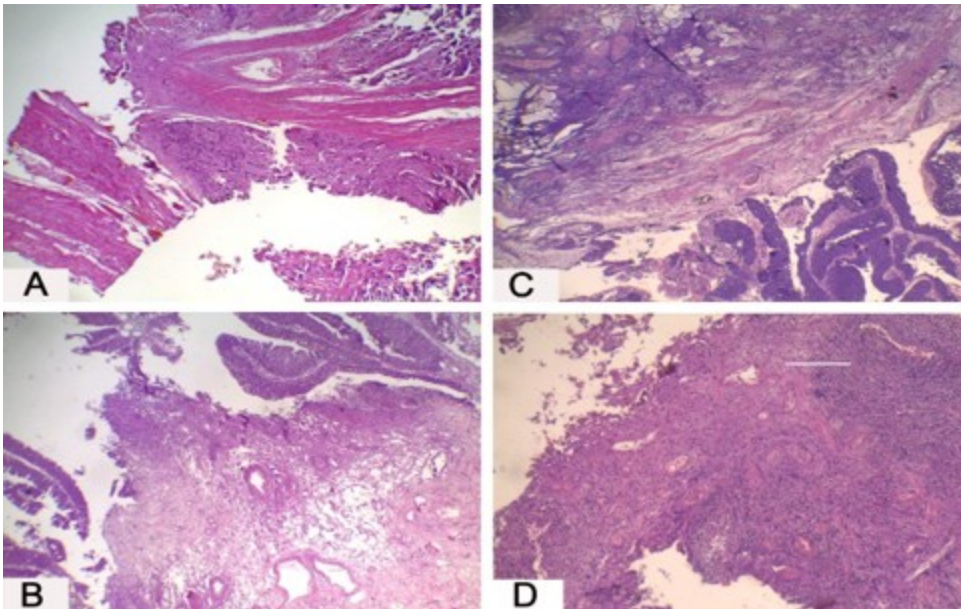


Figure 2

Thulium-Yag laser en bloc resection

(A- a case of high-grade muscle invasive TCC showing no tissue artifact H&E X40, B- a case of non-muscle invasive TCC Ta showing no tissue artifact H&E X40, C- a case of non-muscle invasive TCC Ta showing no tissue artifact H&E X100, D- a case of urothelial carcinoma showing no tissue artifact H&E X100)

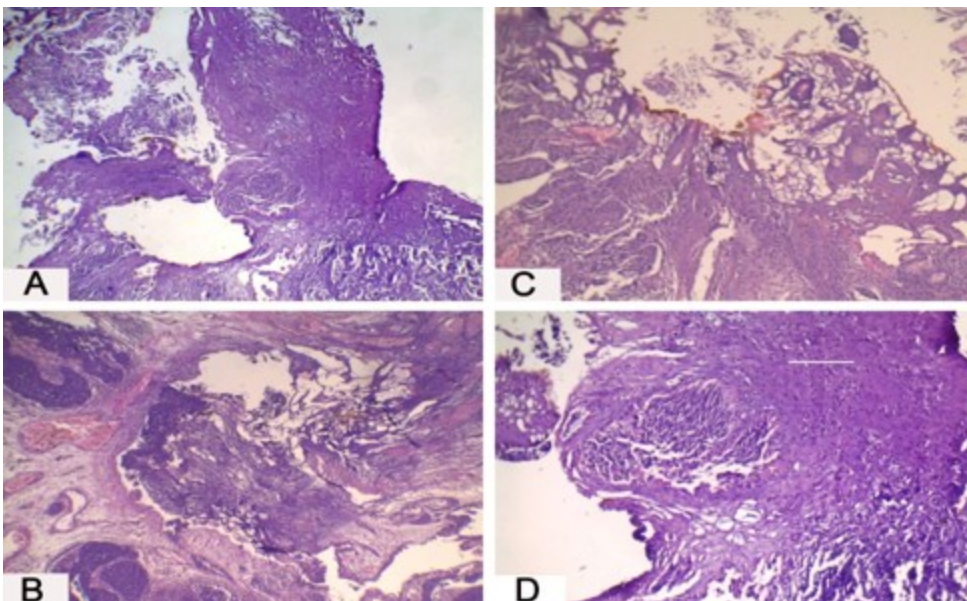


Figure 3

Bipolar en bloc resection

(A-a case of high grade non muscle invasive TCC showing mild cauterization artifact H&E X40, B- a case of low grade non muscle invasive TCC showing marked cauterization artifact H&E X100, C-a case on low grade non muscle invasive papillary TCC showing mild cauterization artifact H&E X40, D-a case of high-grade muscle invasive TCC showing moderate cauterization artifact H&E X100).

Supplementary Files

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