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# Comparative Dosimetric Analysis of Tandem-Ovoid and Tandem-Ring Brachytherapy Applicators in Cervical Cancer

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**ABSTRACT**

Brachytherapy plays a vital role in the treatment of locally advanced cervical cancer by delivering high radiation doses directly to the tumor while minimizing exposure to surrounding healthy tissues. This retrospective study compared the dosimetric performance of tandem–ovoid (T&O) and tandem–ring (T&R) intracavitary brachytherapy applicators in 60 cervical cancer patients treated at CMH Cancer Center, Dhaka. Patients were divided into two groups according to applicator type, with 30 patients in each arm. Dosimetric parameters including HR-CTV 90% coverage, rectal dose, and bladder dose were analyzed. The average HR-CTV 90% coverage was 106.91% for the tandem–ovoid applicator and 100.43% for the tandem–ring applicator. The average rectal dose was lower in the tandem–ring applicator (4.93 Gy) compared to the tandem–ovoid applicator (5.57 Gy). However, the bladder dose was slightly higher in the tandem–ring applicator (5.31 Gy) than in the tandem–ovoid applicator (5.20 Gy). The findings indicate that both applicators provide clinically acceptable dose distribution, although tandem–ovoid demonstrated comparatively better target coverage while tandem–ring showed improved rectal dose sparing. Applicator selection should therefore be individualized according to treatment priorities and patient anatomy.

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## 1. INTRODUCTION

Brachytherapy is a form of internal radiation therapy used to deliver high doses of radiation directly to a tumor while minimizing exposure to surrounding healthy tissues (Viswanathan et al., 2012). Compared with external beam radiotherapy, which treats a broader anatomical region, brachytherapy offers improved dose conformity and reduced toxicity to organs at risk (Sheets et al., 2012). Cervical cancer remains a major global health burden, and brachytherapy is an essential component of curative treatment protocols worldwide (Ferlay et al., 2015; Shrivastava et al., 2013).

Intracavitary brachytherapy (ICBT) is the most commonly used technique for cervical cancer treatment. Among the available applicator systems, tandem and ovoid (T&O) and tandem and ring (T&R) applicators are widely utilized in clinical practice. These applicators differ in geometry and dose distribution characteristics, which may influence target coverage and doses to surrounding organs at risk. Several earlier studies have demonstrated variability in dosimetric outcomes between these applicators depending on patient anatomy and applicator design (Gursel et al., 2020; Rangarajan, 2018; Wolli et al., 1991). Therefore, applicator selection is an important factor for optimizing treatment planning (Nag et al., 2000; Nair et al., 1995).

The objective of this study was to perform a comparative dosimetric analysis of tandem–ovoid and tandem–ring brachytherapy applicators in patients with locally advanced cervical cancer treated at the CMH Cancer Center, Dhaka. Previous evidence suggests that careful optimization of brachytherapy dose delivery is essential for improving local tumor control while minimizing radiation exposure to adjacent normal tissues (Lanciano et al., 1991; Everett et al., 2013). However, outcomes may vary depending on applicator geometry and institutional practice patterns (Jeremic et al., 2020). This study aims to build on these established findings by providing institution-specific dosimetric comparison relevant to clinical decision-making during the study period. Nevertheless, the study was

limited by its retrospective nature, relatively small sample size, and single-center data collection, which may limit broader clinical generalization.

## 2. MATERIALS AND METHODS

This study included 60 patients with histologically confirmed cervical carcinoma who had not received prior treatment. All patients received external beam radiotherapy (EBRT) with a total dose of 50.4 Gy administered in 5 fractions per week over 5 weeks, along with concurrent intravenous cisplatin (40 mg/m²). Following EBRT, patients underwent three weekly sessions of intracavitary brachytherapy (ICBT). Patients were grouped retrospectively according to the applicator type used during treatment: tandem and ovoid applicator (Arm A) and tandem and ring applicator (Arm B), with 30 patients in each group. Each brachytherapy session delivered 700 cGy. Dosimetric data were recorded and analyzed using SPSS version 17.0 (IBM Corp., USA). Although an older version, it is sufficient for the statistical analyses performed in this study. Statistical analysis was performed using Chi-square tests, independent t-tests, and Pearson's correlation coefficient, with statistical significance considered at $p<0.05$. Thus, the effects of different brachytherapy applicator types on target dose, and doses to organs at risk (OARs) were investigated.

### 2.1 Study characteristics

This study included patients with histologically confirmed carcinoma of the cervix. Eligible participants were diagnosed with locally advanced cervical cancer (FIGO stage IIB–IVA). Patients were required to have no prior history of chemotherapy, radiotherapy, or total hysterectomy. All patients had an Eastern Cooperative Oncology Group (ECOG) performance status of ≤2 and no evidence of distant metastasis or obstructive complications. The age range for inclusion was 18 to 70 years. Baseline hematological and biochemical parameters were required to be within acceptable limits, including hemoglobin ≥10 g/dL, white blood cell count ≥4000 cells/mm³, platelet count ≥100,000 cells/mm³, serum bilirubin ≤1.5 mg/dL, SGPT ≤4 times the upper limit of normal, serum creatinine ≤1.5 mg/dL, and blood urea <50 mg/dL.

Patients were excluded if they were pregnant, had serious comorbid conditions such as severe cardiac disease, uncontrolled diabetes mellitus or hypertension, had residual tumor involving more than one-third of the parametrium, life expectancy <6 months, or uncontrolled infections. Patients lost to follow-up or who did not complete treatment were also excluded.

### 2.2 Study Design and Population

This was a retrospective comparative dosimetric study conducted at the CMH Cancer Center, Dhaka. The study included patients with histologically confirmed locally advanced carcinoma of the cervix. All patients had previously received external beam radiotherapy (EBRT) followed by intracavitary brachytherapy (ICBT). Dosimetric data, including target and organs-at-risk (OARs) doses, were extracted from archived treatment plans in the Gamma Med Plus planning system. The study aimed to evaluate and compare dosimetric outcomes between different intracavitary brachytherapy applicator types.

### 2.3 Sampling methods

Patients with histopathologically confirmed cervical carcinoma were selected based on predefined inclusion and exclusion criteria from existing hospital records. No randomization was performed. Sample size was determined to ensure adequate statistical power for comparison between the two study arms.
For sample size measurement, equation **(1)** has been applied.

$$n = \frac{p1(1-p1)+p2(1-p2)}{(p1-p2)^2} \times (Z\alpha + Z\beta)^2 \quad \textbf{(1)}$$

Where,

n is the sample size, p1 is the proportion of patients developing outcome in one arm, p2 is the proportion of patients developing outcome in another arm, Zα = Z value (two tail) at a definite level of significance which is 1.96 at 5% level of significance, and Zβ = Z value (one tail) at a definite power 1.6 at 95% power.

Here, p1 = 50 % (0.5), p2 = 80 % (0.8), Zα = 1.96, Zβ = 1.64.

$$n = \frac{0.5(1-0.5)+0.8(1-0.8)}{(0.5-0.8)^2} \times (1.96+1.64)^2$$

So, n = 60

Thus, a total of 60 patients would be selected as samples. Then, patients were grouped according to the type of intracavitary brachytherapy applicator used during treatment:

- Arm A: tandem and ovoid applicator (n = 30)
- Arm B: tandem and ring applicator (n = 30)

So, 30 patients for each arm will be tested.

### 2.4 Instrumentation

The dosimetric comparison will be conducted using the Varian Brachytherapy machine, a sophisticated device specifically designed for intracavitary brachytherapy. This study involved 60 patients with biopsy-proven, previously untreated cervical carcinoma patients, who were equally divided into two arms: Arm A and Arm B. This new machine provides precise management of radiation delivery, allowing for personalized and individualized targeted treatment strategy tailored to every patient's single case.

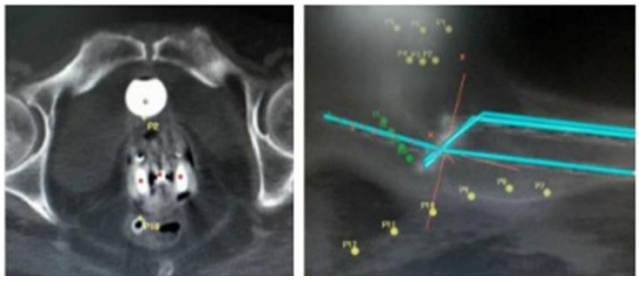
#### 2.4.1 Brachytherapy planning software

To ensure accurate treatment planning and analysis, the study used the Gamma Med Plus software. The highly capable software enables clinicians to conduct meticulous treatment planning with optimal dose distribution within the target location, with minimal radiation exposure to healthy adjacent tissues. Gamma Med Plus is a valuable software for creating patient-specific, anatomy-based treatment plans as well as the nature of the tumor.

2.4.2 Intracavitary brachytherapy (ICBT)

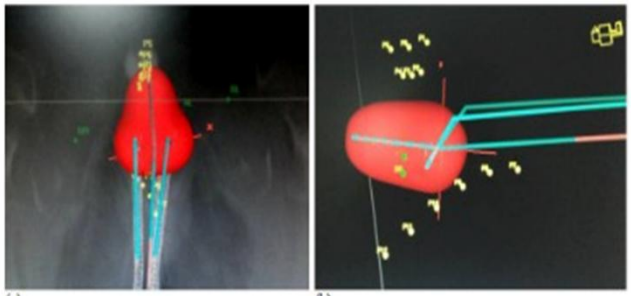
Intracavitary brachytherapy (ICBT) was performed using tandem and ovoid (T&O) and tandem and ring (T&R) applicators. The applicators used in this study were CT-compatible, allowing accurate visualization and reconstruction during treatment planning. These applicators were made of medical-grade stainless steel or titanium to ensure structural stability and biocompatibility during intracavitary insertion. The T&R applicator consisted of a central tandem with a ring component, whereas the T&O applicator consisted of a tandem with two ovoids positioned around the cervix. Treatment planning and dose evaluation were performed using CT-based image-guided brachytherapy techniques.

Figures 1(a) and 1(b) showing CT scan pictures which indicate the labeling of bladder and rectal sites during ICBT. The axial CT scan in Figure 1(a) shows the ICBT applicator with two ovoids and a center tandem. The rectal point is apparent on the anterior surface of the marker tube that is placed into the rectum, but the bladder point is distinguishable on the posterior surface of Foley's bulb. The rebuilt ICBT applicator with several bladder points anteriorly and rectal points posteriorly is displayed in a sagittal CT picture in Figure 1(b).



(a) (b)

**Figure 1:** (a) Axial bladder markings and (b) rectal points depicted in CT scan images.



(a) (b)

**Figure 2:** CT scan images illustrating a pear-shaped isodose distribution on (a) axial and (b) sagittal planes

2.5 Data analysis

A quantitative dosimetric analysis was performed to compare treatment parameters between the two brachytherapy applicator groups. Dose–volume histogram (DVH) analysis was used to evaluate dose distribution to the target volume and organs at risk (OARs). Statistical tests were applied to assess the significance of differences between the tandem–ovoid and tandem–ring applicators, providing a basis for clinical interpretation.

In this retrospective study, data were collected from medical records of 60 patients diagnosed with histologically confirmed locally advanced cervical carcinoma (FIGO stage IIB–IVA). All patients had previously received external beam radiotherapy (EBRT) followed by concurrent chemotherapy and high-dose-rate intracavitary brachytherapy (HDR-ICBT). The median age of the cohort was 53 years (range: 25–81 years). Clinical staging was limited to FIGO stage IIB–IVA as per the study inclusion criteria.

## 3. RESULTS AND DISCUSSIONS

The study included 60 patients who were divided into two groups based on the type of intracavitary brachytherapy applicator used: tandem–ovoid (Arm A) and tandem–ring (Arm B). Dosimetric evaluation was performed using dose–volume histogram (DVH) analysis to compare target coverage and doses to organs at risk.

The prescribed dose distribution and coverage of the Clinical Target Volume–High Risk (CTV-HR) are summarized in Table 1. A comparative analysis between the two applicators demonstrated differences in dose distribution patterns, with variations in target coverage and organ-at-risk sparing observed between the groups. These findings are consistent with previous studies reporting that applicator geometry significantly influences dose distribution in intracavitary brachytherapy for cervical cancer. Gursel et al. (2020) observed that differences in applicator design affect dose distribution, particularly in relation to rectal and bladder dose sparing. Similarly, Rangarajan (2018) demonstrated that tandem–ring and tandem–ovoid applicators produce distinct dose distribution patterns, influencing both target coverage and organ-at-risk doses. Earlier recommendations by Nag et al. (2000) also highlighted the importance of appropriate applicator selection in achieving optimal dose distribution in high-dose-rate brachytherapy for cervical cancer.

Overall, the present study supports existing evidence that applicator geometry plays a critical role in dose optimization and treatment planning in intracavitary brachytherapy for cervical cancer.

**Table 1:** HR-CTV Coverage and Dose Optimization before treatment

| Patient No. | Central Tandem with Ring Applicator CTV-HR | 3-Channel Tandem with 2 Ovoids CTV-HR 90% (%) |
|---|---|---|

| | 90% (%) | |
|---|---|---|
| 1 | 90.00 | 64.00 |
| 2 | 90.00 | 90.00 |
| 3 | 90.00 | 90.00 |
| 4 | 90.00 | 90.00 |
| 5 | 90.00 | 90.00 |
| 6 | 90.00 | 90.00 |
| 7 | 90.00 | 90.00 |
| 8 | 90.00 | 90.00 |
| 9 | 90.00 | 90.00 |
| 10 | 101.00 | 93.00 |
| 11 | 102.00 | 93.00 |
| 12 | 107.00 | 99.50 |
| 13 | 107.00 | 100.00 |
| 14 | 109.00 | 101.00 |
| 15 | 111.00 | 102.00 |
| 16 | 115.00 | 102.00 |
| 17 | 115.00 | 103.00 |
| 18 | 116.00 | 103.00 |
| 19 | 119.00 | 103.00 |
| 20 | 120.00 | 104.00 |
| 21 | 121.00 | 105.00 |
| 22 | 122.00 | 105.00 |
| 23 | 122.00 | 106.00 |
| 24 | 123.00 | 106.00 |
| 25 | 125.00 | 106.80 |
| 26 | 125.00 | 107.00 |
| 27 | 125.00 | 107.00 |
| 28 | 125.00 | 108.00 |
| 29 | 125.17 | 109.00 |
| 30 | 125.17 | 112.00 |
| 31 | 127.00 | 112.00 |
| 32 | 129.00 | 113.00 |
| 33 | 130.00 | 117.00 |
| 34 | 134.00 | 117.38 |
| 35 | 149.00 | 118.00 |
| 36 | 151.00 | 118.00 |
| 37 | | 119.00 |
| 38 | | 131.00 |
| 39 | | 141.00 |
| 40 | | 148.00 |
| 41 | | 158.00 |
| 42 | | 162.00 |
| 43 | | 176.00 |
| 44 | | 184.00 |

Table 1 shows the comparison of HR-CTV dose coverage between the tandem–ring and tandem–ovoid applicator groups. A total of 36 cases were analyzed in the central tandem with ring applicator group, while 44 cases were included in the 3-channel tandem with 2 ovoids applicator group. The prescribed dose was 7.0 Gy in all cases. The tandem–ring applicator group demonstrated greater variability in HR-CTV coverage, with several values exceeding 120% and reaching up to 151%, indicating a more heterogeneous dose distribution. In contrast, the tandem–ovoid group showed more consistent and stable coverage, with most values closer to the prescribed dose level. Overall, the results suggest that applicator type influences dose distribution, with tandem–ring showing higher variability compared to tandem–ovoid.

The fluctuation in coverage, measured in terms of effective dose, for both the tandem ring applicator (CTV 90%) and the 3-channel tandem with 2 ovoids (CTV 90%) are shown in Figure 3.

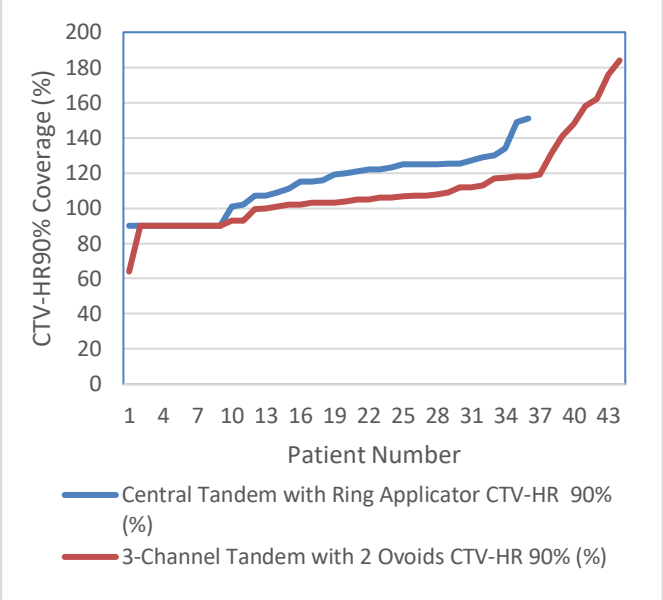



**Figure 3:** Comparison of hr-ctv90% coverage between tandem-ring applicator (ctv 90%) and 3 channel tandems with 2 ovoids (ctv 90%)

This graph shows the HR-CTV 90% coverage for all patients in comparison to two intracavitary brachytherapy applicators. Overall, the central tandem with ring applicator had relatively higher and more consistent HR-CTV 90% coverage for most patients, which was gradually increased from ~90% to ~150%. The 3-channel tandem with the 2 ovoids applicator demonstrated lower coverage in most instances, consistently around 100-120% until it increased significantly in a few.

The results suggest that the central tandem with ring applicator might offer a more consistent and uniform dose coverage to HR-CTV, while 3-channel tandem with 2 ovoids applicator might give a more variable dose coverage with the potential for higher dose values in certain areas. Detailed dosimetric data are provided in Supplementary Table S1. It compares rectal dose (2 cc) and its percentage coverage between tandem–ring and tandem–ovoid applicator groups. Data include 74 measurements for the tandem–ring applicator group and 70 measurements for the tandem–ovoid applicator group. Both groups received a prescribed dose of 7 Gy per fraction. Overall, the tandem–ring applicator showed relatively lower and more variable rectal dose coverage, whereas the tandem–ovoid group demonstrated comparatively higher and more consistent rectal dose values. Some outlier values with higher rectal dose percentages were observed in both groups, but variability appeared greater in the tandem–ring group. These

findings indicate that applicator type may influence rectal dose exposure, with potential implications for organ-at-risk sparing during intracavitary brachytherapy.

The box and whisker plot in Figure 4, shows that median coverage of the Central Tandem with 2 Ovoid applicator was higher than for the Central Tandem Ring Applicator technique (approx. 78% vs. approx. 66%), and the interquartile range was narrower, suggesting that there was less variability in coverage, while the Ring Applicator technique had one extreme outlier around 230% indicating high exposure to rectal dose or heterogeneity in cases.

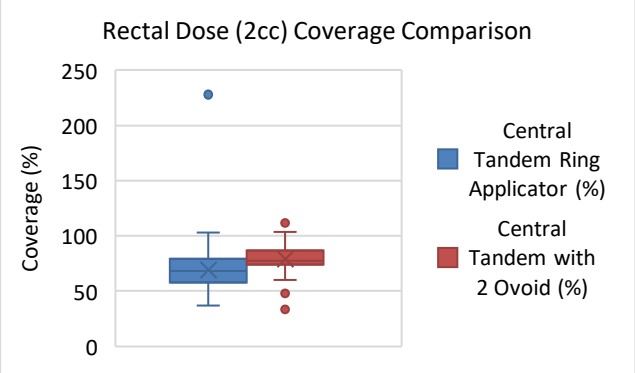



**Figure 4:** Box-and-whisker plot comparing rectal dose (2cc, 2%) between tandem-ring applicator and 3-channel tandem with 2 ovoids

The prescribed dose and bladder dose coverage before treatment are given in Table 3.

**Table 3:** Prescribed dose and bladder dose coverage for Pre-treatment

| Case No. | Central Tandem Ring Applicator (%) | Central Tandem with 2 Ovoids (%) |
|---|---|---|
| 1 | 45.0 | 42.8 |
| 2 | 45.0 | 48.0 |
| 3 | 48.0 | 51.0 |
| 4 | 54.0 | 51.0 |
| 5 | 55.0 | 55.0 |
| 6 | 58.0 | 60.9 |
| 7 | 59.0 | 61.0 |
| 8 | 60.0 | 62.0 |
| 9 | 60.0 | 62.0 |
| 10 | 63.0 | 63.0 |
| 11 | 63.0 | 63.0 |
| 12 | 64.0 | 63.5 |
| 13 | 64.0 | 66.4 |
| 14 | 65.0 | 66.7 |
| 15 | 65.0 | 68.5 |
| 16 | 67.0 | 70.0 |
| 17 | 69.0 | 70.7 |
| 18 | 69.0 | 71.0 |
| 19 | 69.0 | 73.0 |
| 20 | 70.0 | 74.0 |
| 21 | 71.0 | 78.0 |
| 22 | 71.0 | 78.0 |
| 23 | 71.0 | 79.0 |
| 24 | 74.0 | 79.0 |
| 25 | 74.0 | 81.0 |
| 26 | 77.0 | 82.0 |
| 27 | 78.0 | 82.0 |
| 28 | 80.0 | 82.0 |
| 29 | 80.0 | 83.0 |
| 30 | 87.0 | 83.0 |
| 31 | 87.0 | 84.0 |
| 32 | 88.0 | 86.0 |
| 33 | 88.0 | 87.0 |
| 34 | 88.0 | 87.0 |
| 35 | 89.0 | 89.0 |
| 36 | 89.0 | 90.0 |
| 37 | 94.0 | 92.0 |
| 38 | | 92.8 |
| 39 | | 93.5 |
| 40 | | 94.0 |
| 41 | | 95.0 |
| 42 | | 95.0 |

The comparison of the coverage of bladder dose (2 cc) between the central tandem-ring applicator and the central tandem with 2 ovoid applicator groups is presented in Table 3. The prescribed dose to both groups was 7Gy/fraction. The results show the application group with tandem–ring applicators had a varying extent of dose coverage for the bladder, from about 45% to 94%. In contrast, the tandem with 2 ovoids group showed coverage values from approximately 42.8% to 95%, with most coverage values were in the range of 70 to 90%, which indicates more comparable dose distribution. Tandem–ring group demonstrated more variation in the coverage values, suggesting less homogeneous bladder dose distribution. The tandem with 2 ovoids applicator gave relatively uniform and stable bladder coverage, however. Some higher values were observed in both groups, and this may be due to differences in the geometry of the applicators, patient anatomy, bladder filling and positioning of the applicators during treatment.

Figure 5 illustrates the bladder dose 2cc 2% for the Tandem Ring Applicator and the 3-channel Tandem with 2 Ovoids in different cases.

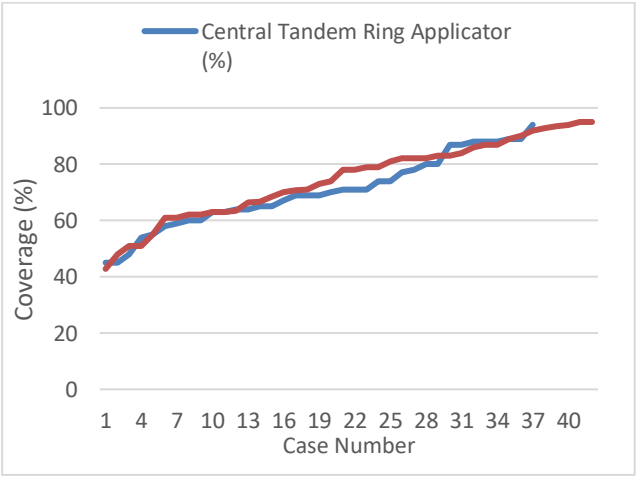


**Figure 5:** Comparison of bladder 2cc 2%dose coverage between tandem ring applicator and 3-channel tandem with 2 ovoids

The overall pattern of the applicator systems, in Figure 5, was similar throughout the cases of treatment with a progressive response in coverage for both systems. For the lower and mid-range case numbers, the 3-channel Tandem with 2 Ovoids was slightly more effective in achieving bladder dose coverage than the Tandem Ring Applicator. In the later cases, however, the Tandem Ring Applicator demonstrated a slight improvement, and obtained slightly higher maximum coverage values.

**Table 4:** Performance analysis between the central tandem ring applicator and the central tandem with 2 ovoids in terms of coverage

| No | Parameter | Central tandem with ring applicator | Central tandem with 2 ovoids | Central tandem with ring applicator | Central tandem with 2 ovoids | Central tandem with ring applicator | Central tandem with 2 ovoids |
|---|---|---|---|---|---|---|---|
| | | CTV-HR 90% | CTV-HR 90% | Rectal dose | Rectal dose | Bladder dose | Bladder dose |
| 1. | Average coverage (%) | 100.43 | 106.91 | 71.75 | 80.16 | 78.05 | 76.67 |
| 2. | Average coverage difference between central tandem ring applicator and Central tandem with 2 ovoids (%) | | 6.48 | 8.41 | | 1.38 | |

Table 4 illustrates the performance comparison between the central tandem ring applicator and the central tandem with two ovoids in terms of coverage. The average coverage difference between the central tandem ring applicator and the central tandem with two ovoids is 6.48% for CTV-HR 90%, 8.41% for rectal dose, and 1.38% for bladder dose. The average coverage for the central tandem with a ring applicator (CTV-HR 90%) is lower than that for the central tandem with two ovoids (CTV-HR 90%). Furthermore, the average coverage for the central tandem with two ovoids (rectal dose) is higher than for the central tandem with a ring applicator (rectal dose). Additionally, the average coverage for the central tandem with two ovoids (bladder dose) is lower than for the central tandem with a ring applicator (bladder dose).

**Table 5:** Performance analysis of central tandem ring applicator and central tandem with 2 ovoids according to dose

| **No** | **Parameter** | **Central tandem with ring applicator** | **Central tandem with 2 ovoids** | **Central tandem with ring applicator** | **Central tandem with 2 ovoids** |
|---|---|---|---|---|---|
| | | **Rectal dose** | **Rectal dose** | **Bladder dose** | **Bladder dose** |
| 1. | Average dose (Gy) | 4.93 | 5.57 | 5.31 | 5.20 |
| 2. | Average dose difference between central tandem ring applicator and Central tandem with 2 ovoids (Gy) | 0.64 | | 0.11 | |

Table 5 presents the performance comparison between the central tandem ring applicator and the central tandem with two ovoids in terms of dose. The average dose difference between the central tandem ring applicator and the central tandem with two ovoids is 0.64 for the rectal dose and 0.11 for bladder dose. The average dose for the central tandem with a ring applicator (rectal dose) is lower than that for the central tandem with two ovoids (rectal dose). Conversely, the average dose for the central tandem with a ring applicator (bladder dose) is higher than that for the central tandem with two ovoids (bladder dose).

Based on the findings presented in Tables 4 and 5, the central tandem with two ovoids generally offers better coverage than the central tandem ring applicator, particularly in terms of CTV-HR 90% and rectal dose. However, for bladder dose, the central tandem ring applicator provides superior coverage compared to the two ovoids. In terms of average dosage, the ring applicator results in a higher dose to the bladder, while the two ovoids deliver a higher dose to the rectum. When optimizing overall coverage, especially for CTV-HR 90% and minimizing rectal exposure, the central tandem ring applicator appears to be the more effective option. On the other hand, if bladder dose reduction is a greater priority, the central tandem with two ovoids may be the preferred treatment choice.

This study demonstrates that applicator type and brachytherapy technique significantly influence outcomes in the management of locally advanced cervical cancer. The findings support the advancement of personalized treatment strategies to optimize patient care.

## 4. CONCLUSION

This retrospective comparative study evaluated the dosimetric differences between tandem–ovoid and tandem–ring brachytherapy applicators in patients with locally advanced cervical cancer. The tandem–ovoid applicator demonstrated higher average HR-CTV 90% coverage (106.91%) compared with the tandem–ring applicator (100.43%). In contrast, the tandem–ring applicator produced a lower average rectal dose (4.93 Gy) than the tandem–ovoid applicator (5.57 Gy), indicating improved rectal sparing. The average bladder dose was slightly higher in the tandem–ring applicator (5.31 Gy) compared to the tandem–ovoid applicator (5.20 Gy).

The findings suggest that tandem–ovoid applicators may provide superior target coverage, whereas tandem–ring applicators may offer better rectal dose optimization in selected patients. Therefore, applicator selection should be individualized according to tumor characteristics, organ-at-risk constraints, and clinical treatment priorities. This study supports the importance of optimized applicator selection in improving treatment planning and reducing radiation-related toxicity in cervical cancer brachytherapy.

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## DATA AVAILABILITY STATEMENT

Datasets generated during the current study are available from the corresponding author upon reasonable request.

## FUNDING DECLARATION

This research was self-funded.

## ETHICS APPROVAL

This study is an engineering experimental investigation. The MIJST Research Ethics Committee has confirmed that formal ethical approval was not required.

## ETHICS, CONSENT TO PARTICIPATE, AND CONSENT TO PUBLISH

Not applicable.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

## AUTHOR CONTRIBUTIONS

Author 1: Study design, clinical procedures, data collection, and data analysis.
Author 2: Supervision, methodology guidance, and manuscript review.
Author 3: Data analysis, literature review, and visualization.
Author 4: Data processing and literature review.
Author 5: Manuscript preparation, reference management, and final proofreading.
Author 6: Clinical support and data acquisition.
Author 7: Technical validation and treatment planning support.
Author 8: Project oversight and technical guidance.
Author 9: Expert consultation and scientific review.

## ARTIFICIAL INTELLIGENCE ASSISTANCE STATEMENT

Portions of this manuscript were assisted by an artificial intelligence language model (ChatGPT, OpenAI). The tool was used solely for language editing, text refinement, and improving clarity. All content, data interpretation, analysis, conclusions, and final decisions were produced, verified, and approved by the authors. The authors take full responsibility for the accuracy and integrity of the manuscript.

## CONFLICT OF INTEREST DECLARATION

The authors declare that they have no conflicts of interest.

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## Supplementary Material

**Supplementary Table S1:** Detailed dosimetric parameters of tandem–ovoid and tandem–ring applicators in cervical cancer brachytherapy.

| Central Tandem Ring Applicator (%) | Central Tandem with 2 Ovoid (%) |
|---|---|
| 36 | 33 |
| 36 | 67 |
| 42 | 72 |
| 42 | 72 |
| 43 | 73 |
| 45 | 73 |
| 48 | 73 |
| 49 | 73 |
| 50 | 74 |
| 52 | 74 |
| 53 | 74 |
| 54 | 75 |
| 55 | 75 |
| 55 | 75 |
| 56 | 75 |
| 57 | 75 |
| 58 | 76 |
| 58 | 76 |
| **Central Tandem Ring Applicator (%)** | **Central Tandem with 2 Ovoid (%)** |
| 58 | 76 |
| 58 | 76 |
| 58 | 76 |
| 59 | 77 |
| 61 | 77 |
| 62 | 78 |
| 62 | 79 |
| 73 | 79 |
| 79 | 79 |
| 79 | 83 |
| 79 | 87 |

| | |
|---|---|
| 80 | 88 |
| 81 | 92 |
| 81 | 92 |
| 82 | 95 |
| 82 | 98 |
| 89 | 48 |
| 103 | 48 |
| 228 | 50 |
| 59 | 54 |
| 61 | 60 |
| 62 | 62 |
| 63 | 67 |
| 63 | 68 |
| 64 | 70 |
| 65 | 72 |
| 65 | 74 |
| 65 | 76 |
| 67 | 76 |
| 68 | 76.4 |
| 68 | 76 |
| 68 | 77 |
| 68 | 78 |
| 69 | 79 |
| 70 | 80 |
| 70 | 81 |
| 70 | 82 |
| 71 | 82 |
| 71 | 82 |
| 71 | 82 |
| 71 | 83 |
| 71 | 83 |
| 72 | 84 |
| 73 | 85 |
| 73 | 85 |
| 81 | 86 |
| 82 | 87 |
| 82 | 88 |
| 83 | 89 |
| 83 | 89 |
| 83 | 90 |
| 84 | 90 |
| 85 | 91 |
| 85 | 92 |
| 86 | 93 |
| | 95 |
| | 96 |
| | 99 |
| | 103 |
| | 111 |