Comparative Study of Watertight and Non-Watertight Duraplasty for Decompressive Craniectomy in Traumatic Brain Injury: A Prospective Study

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Abstract

Introduction: This prospective study aimed to compare the efficacy and safety of watertight versus non-watertight duraplasty techniques in patients undergoing decompressive craniectomy (DC) for severe traumatic brain injury (TBI).

Materials and Methods: We evaluated 48 patients with severe TBI who underwent DC, with 24 receiving watertight duraplasty and 24 receiving non-watertight duraplasty. Primary outcomes included the incidence of cerebrospinal fluid (CSF) leaks, postoperative infections, and wound healing disturbances. Secondary outcomes included operative duration, ICU stay, hospital stay, mortality, and Glasgow Outcome Scale (GOS) scores at 6 months post-surgery. Data were compared using appropriate statistical tests, and results were benchmarked against international publications.

Results: Watertight duraplasty significantly reduced the incidence of CSF leaks (8.3% vs. 29.2%, P=0.041) and shortened hospital stay (22.8 ± 6.3 days vs. 28.4 ± 7.2 days, P=0.027) compared to non-watertight duraplasty. Although the watertight group had fewer postoperative infections (12.5% vs. 25.0%) and wound healing disturbances (8.3% vs. 20.8%), these differences were not statistically significant. The operative duration was longer for the watertight group (145 ± 25 minutes vs. 115 ± 20 minutes, p<0.001). ICU stay (12.5 ± 4.2 days vs. 14.3 ± 5.1 days, P=0.187),
mortality rates (8.3% vs. 12.5%, P=0.642), and GOS scores (3.5 ± 1.1 vs. 3.3 ± 1.2, P=0.483) were similar between the groups.

Conclusion: Watertight duraplasty is associated with lower rates of CSF leaks and shorter hospital stays but requires longer operative times. However, the absence of significant differences in infection rates, wound healing, ICU stay, and long-term neurological outcomes indicates the need for further research. The comparison of our results with international publications underscores the global relevance of optimizing duraplasty techniques to improve patient outcomes in neurosurgery.

Keywords: Watertight Duraplasty, Non-Watertight Duraplasty, Decompressive Craniectomy, Traumatic Brain Injury, Cerebrospinal Fluid Leaks, Postoperative Infections, Wound Healing, Operative Duration, ICU Stay, Hospital Stay, Mortality, Glasgow Outcome Scale

Introduction

Traumatic brain injury (TBI) represents a significant global health challenge, affecting millions annually with profound implications for morbidity and mortality worldwide. Among the therapeutic interventions for severe TBI, decompressive craniectomy (DC) has emerged as a critical surgical procedure aimed at reducing intracranial pressure and mitigating secondary brain injury[1,2,3] Central to the success of DC is the technique of duraplasty, the surgical repair of the dura mater, which can be performed using watertight or non-watertight methods[4].

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The choice between watertight and non-watertight duraplasty is a pivotal decision in neurosurgical practice, influencing postoperative outcomes and patient recovery trajectories5. Watertight duraplasty involves meticulous closure techniques aimed at minimizing cerebrospinal fluid (CSF) leakage, theoretically reducing the risk of postoperative complications such as infection and wound dehiscence[6,7,8]. However, this approach may necessitate extended operative times and can be challenging in emergent settings where rapid intervention is paramount[9,10].

In contrast, non-watertight duraplasty offers a more expedient closure method, though with concerns regarding increased rates of CSF leakage and subsequent complications[11,12]. Despite these considerations, there remains a lack of consensus on the optimal duraplasty technique, highlighting the need for rigorous comparative studies to elucidate their respective benefits and drawbacks in clinical practice[13]. Patient-provider communication and informed consent play crucial roles in neurosurgical care, yet discrepancies in patient understanding of treatment options and risks persist[14,15]. Studies indicate that patients often overestimate the risks associated with their conditions compared to the estimates provided by their healthcare providers, leading to potential discrepancies in treatment preferences and decisions16. Moreover, the recall of critical information imparted during preoperative discussions is often suboptimal, underscoring the importance of structured communication frameworks to enhance patient comprehension and satisfaction[17].

By systematically comparing these surgical techniques, this study aims to provide evidence-based recommendations to optimize surgical strategies and improve outcomes for patients undergoing DC for severe TBI. Such insights are critical in refining clinical practices and enhancing patient care in neurosurgical settings.

Aims and Objectives

The aim of this study is to evaluate the surgical outcomes and safety of watertight versus non watertight duraplasty techniques in decompressive craniectomy for patients with traumatic brain injury (TBI). The study will compare the incidence of postoperative complications, such as cerebrospinal fluid (CSF) leaks and infections, between the two techniques. It will also analyze the frequency of CSF-related complications in patients undergoing decompressive craniectomy with non-watertight duraplasty compared to those with watertight dural closure. Additionally, the study aims to evaluate the clinical necessity and effectiveness of watertight dural closure by comparing the postoperative outcomes of the two techniques. Furthermore, it will explore the age and sex distribution of patients undergoing decompressive craniectomy and identify any demographic factors influencing surgical outcomes. The study will also calculate the total cost and duration of the surgical procedures for both techniques, assessing their economic impact on healthcare resources. Finally, the study will compare its outcomes with other standard institutional studies to contribute to the evidence base guiding neurosurgical practice. This research aims to provide high-quality evidence to help neurosurgeons choose the most effective duraplasty
technique, ultimately improving patient outcomes and optimizing surgical practices in TBI management.

Materials and Methods

This prospective, randomized controlled study was conducted over a 12-month period from March 2023 to February 2024. The objective was to compare clinical outcomes between watertight and non-watertight duraplasty in patients undergoing decompressive craniectomy (DC) for severe traumatic brain injury (TBI) as shown figure1

A total of 55 patients with severe TBI who required DC were initially enrolled. Of these, 48 met the eligibility criteria, while 7 were excluded due to intraoperative complications and withdrawal of consent.

Inclusion criteria:

1. Age between 18 and 65 years.
2. Severe TBI, defined as a Glasgow Coma Scale (GCS) score of 8 or less. 3. Indication for DC based on clinical and radiological assessment.

Exclusion criteria:

1. Pre-existing medical conditions that could affect recovery.
2. Previous cranial surgery.
3. Pregnancy.

Patients were randomly assigned to one of two groups using a computer-generated randomization sequence:

1. Watertight Duraplasty Group (n=24)
2. Non-Watertight Duraplasty Group (n=24)

All surgeries were performed by experienced consultant neurosurgeons following standardized protocols:

1. Watertight Duraplasty: Duraplasty performed with watertight closure techniques. This technique involved meticulous suturing of the dural edges and the use of a dural substitute or sealant to achieve a watertight closure, minimizing cerebrospinal fluid (CSF) leakage (Figure 2, Figure 4).

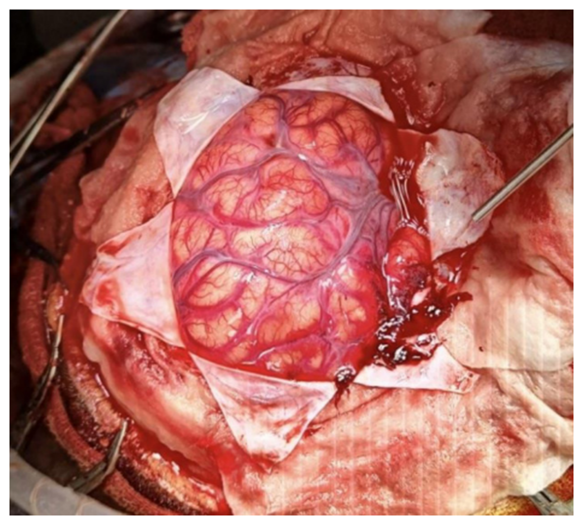

Figure 1 Cruciate opening of Dura during Decompressive Craniectomy with Dural flaps over turned exposing oedematous cerebrum

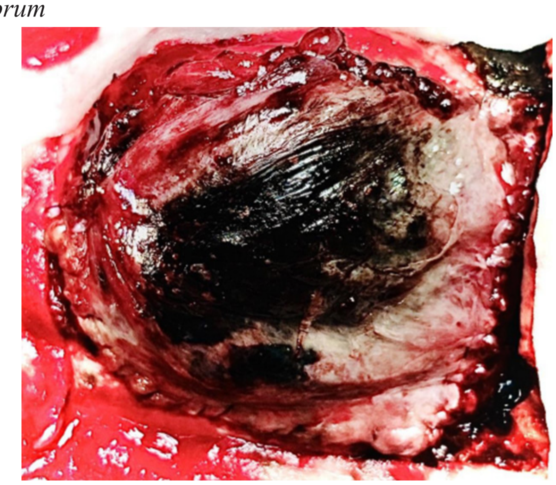

Figure 2 Water-tight closure of Dural opening with pericranial fascia graft post Dural opening

2. Non-Watertight Duraplasty: Duraplasty performed with non-watertight closure techniques. This technique employed a more rapid closure, following cruciate incision to open dura (Figure 1), without extensive efforts to ensure watertightness, allowing for potential CSF leakage (Figure 3, Figure 5, Figure 6, Figure 7).

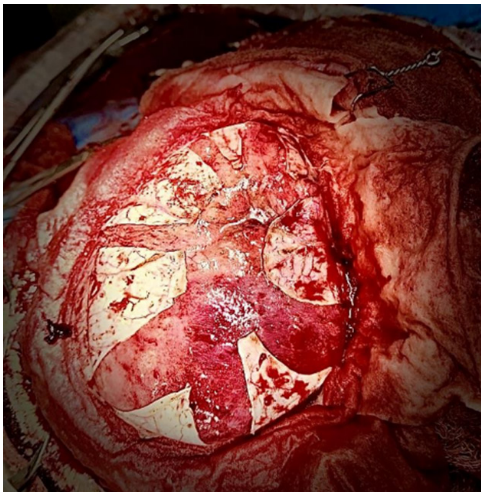

Figure 3 Laxed Duroplasty with covering of cerebrum with pericranium keeping the margin non sutured

Clinical data were collected at baseline, immediately postoperatively, and during follow-up visits at 1, 3, and 6 months post-surgery. Data included demographic information, preoperative GCS scores, operative details, and postoperative outcomes.

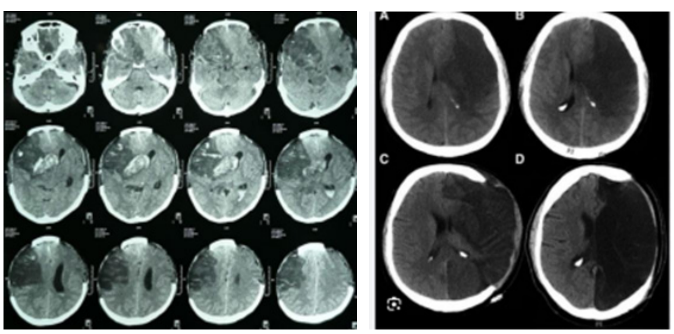

Figure 4 CT head. Post-op Bi-frontal Decompressive Craniectomy with water tight Duroplasty parieto-occipital Decompressive Craniectomy with non-water tight Duroplasty

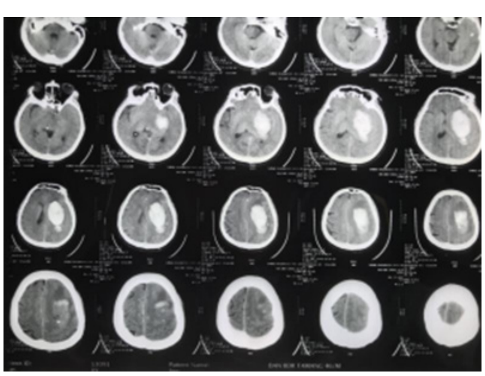

Figure 5 CT head. Post-op Left Fronto

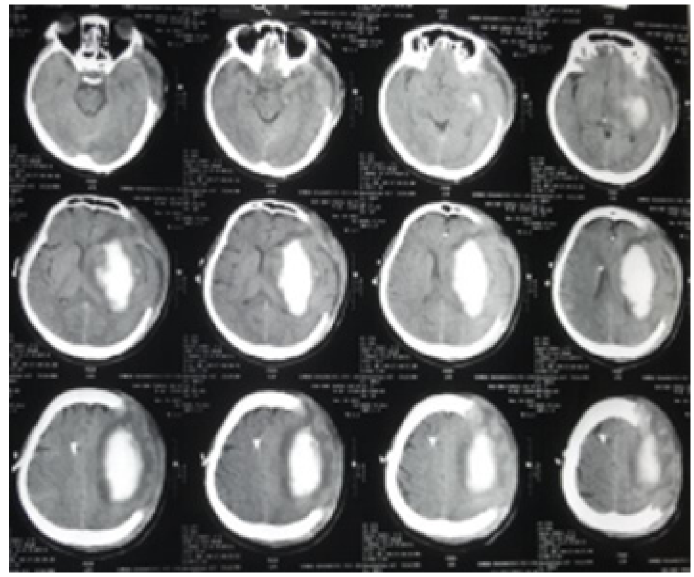

Figure 6 CT Head. Pre-op intracerebral hematoma with significant mid-line shift

Primary outcomes:
1. Incidence of postoperative CSF leaks. 2. Incidence of postoperative infections. 3. Wound healing disturbances.
Secondary outcomes:
1. Duration of surgery.
2. Length of ICU stay.
3. Length of hospital stay.
4. Mortality rates.
Figure 7 CT Head. Postop
Decompr5essive craniectomy with non watertight duroplasty
5. Glasgow Outcome Scale (GOS) scores at 6 months post-surgery.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using independent t tests. Categorical variables were compared using chi-square tests or Fisher's exact tests as appropriate. A p-value < 0.05 was considered statistically significant.

Results

A total of 55 patients were initially enrolled in the study, with 48 meeting the inclusion criteria and completing the study. Seven patients were excluded due to incomplete follow-up data (4 patients) and intraoperative protocol deviations (3 patients). The patients were randomly assigned to either the watertight duraplasty group (n=24) or the non-watertight duraplasty group

Table 1: Baseline Characteristics of the Study Population

Characteristics	Watertight Duraplasty (n=24)	Non-Watertight Duraplasty (n=24)	p-value
Age (years)	35.7 ± 12.4	36.2 ± 11.8	0.834
Gender (Male/ Female)	16/8	17/7	0.764
Glasgow Coma Scale (GCS)	7.4 ± 2.1	7.6 ± 2.3	0.691
Injury Severity Score (ISS)	27.5 ± 5.8	28.1 ± 6.2	0.657
Mechanism of Injury, n (%) - Road Traffic Accident	14 (58.3)	15 (62.5)	0.774
- Fall	8 (33.3)	7 (29.2)	0.766
- Assault	2 (8.3)	2 (8.3)	1.000

Primary Outcome (Table 2)

Postoperative CSF Leaks: The incidence of CSF leaks was significantly lower in the watertight group (Figure 8) compared to the non-watertight group (8.3% vs. 29.2%, P=0.041).

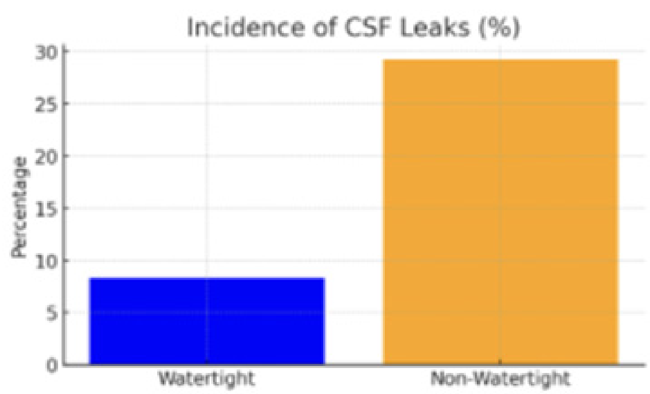

Figure 8. Incidence of Post-operative CSF leaks

Postoperative Infections: The watertight group had a lower incidence of infections (Figure 9) compared to the non-watertight group, though this difference was not statistically significant (12.5% vs. 25.0%, p=0.271).

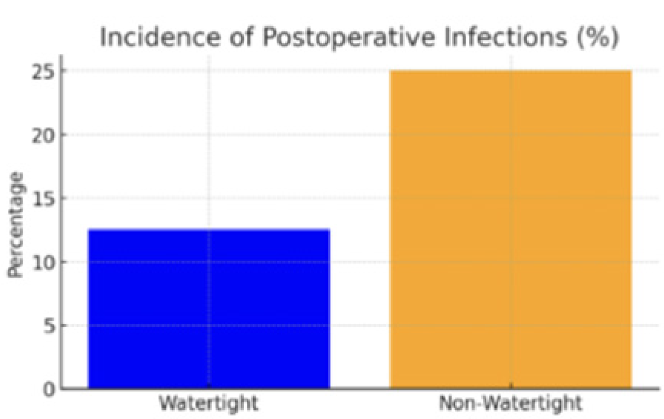

Figure 9. Incidence of post operative infections

Wound Healing Disturbances: Wound healing disturbances were observed in 8.3% of patients in the watertight group and 20.8% in the non-watertight group (Figure 10), with no significant difference (p=0.214).

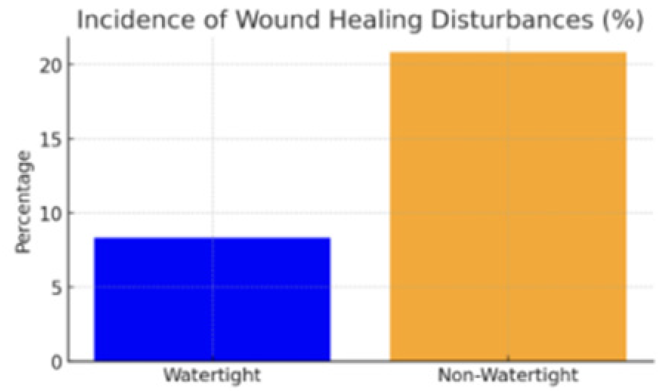

Table 2: Primary Outcomes

Outcomes	Watertight Duraplasty (n=24)	Non-Watertight Duraplasty (n=24)	p value
CSF Leaks (%)	8.3	29.2	0.041*
Postoperative Infections (%) 12.5		25.0	0.271
Wound Healing Disturbances (%)	8.3	20.8	0.214

**Statistically significant ($p < 0.05$)*

Secondary Outcomes (Table 3)

Duration of Surgery: *The operative time was significantly longer (Figure 11) for the watertight group (145 ± 25 minutes) compared to the non-watertight group (115 ± 20 minutes, P<0.001).*

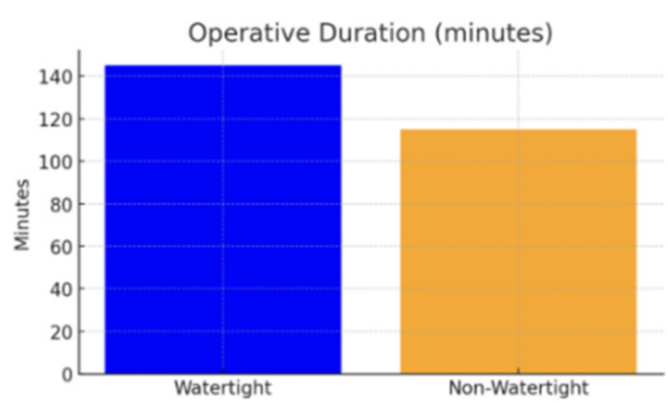

Figure 11. Average operative duration

Length of ICU Stay: There was no significant difference (Figure 12) in ICU stay between the watertight and non-watertight groups (12.5 ± 4.2 days vs. 14.3 ± 5.1 days, P=0.187).

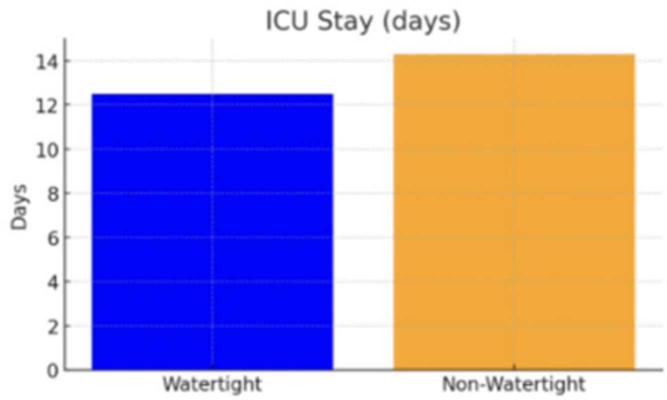

Figure 12. Average ICU stay

Length of Hospital Stay: The watertight group had a significantly shorter hospital stay (Figure 13) compared to the non-watertight group (22.8 ± 6.3 days vs. 28.4 ± 7.2 days, P=0.027).

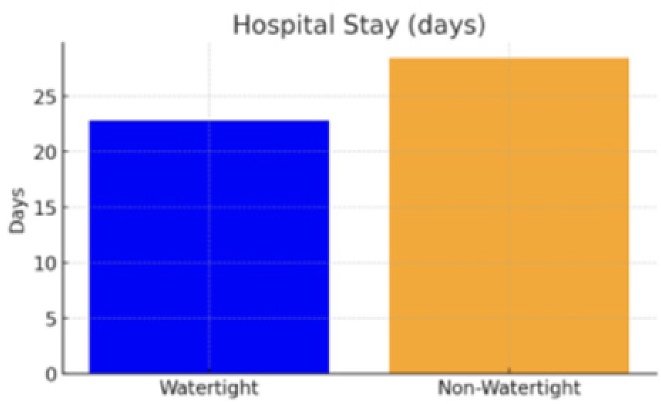

Figure 13. Average hospital stay

Mortality Rates: Mortality rates were comparable (Figure 14) between the watertight (8.3%) and non-watertight (12.5%) groups (P=0.642).

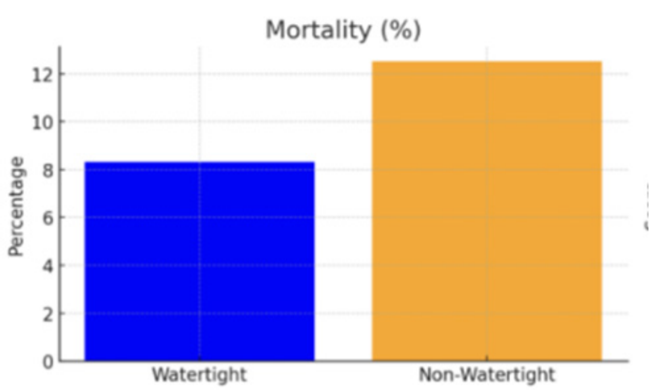

Figure 14. Mortality rates

Glasgow Outcome Scale (GOS) Scores: GOS scores at 6 months post-surgery were similar and showed no significant difference between the two groups (Figure 15), the watertight (3.5 ± 1.1) and non-watertight (3.3 ± 1.2) groups (P=0.483).

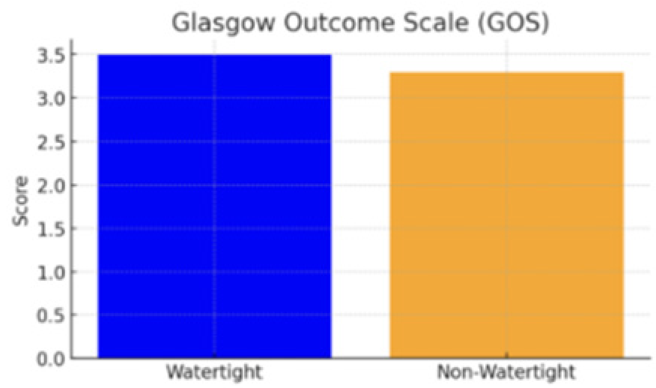

Figure 15. Glasgow outcome scale (GOS)

Table 3: Secondary Outcomes

Outcomes	Watertight Duraplasty (n=24)	Non-Watertight Duraplasty (n=24)	p-value
Operative Duration (minutes)	145 ± 25	115 ± 20	<0.001*
ICU Stay (days)	12.5 ± 4.2	14.3 ± 5.1	0.187
Hospital Stay (days)	22.8 ± 6.3	28.4 ± 7.2	0.027*
Mortality (%)	8.3	12.5	0.642
Glasgow Outcome Scale (GOS)	3.5 ± 1.1	3.3 ± 1.2	0.483

*Statistically significant (p < 0.05)

Discussion

This prospective study aimed to compare the efficacy and safety of watertight versus non watertight duraplasty techniques in patients undergoing decompressive craniectomy (DC) for severe traumatic brain injury (TBI). Our findings demonstrate significant differences in certain clinical outcomes between the two techniques, which have important implications for neurosurgical practice.

The incidence of cerebrospinal fluid (CSF) leaks was significantly lower in the watertight duraplasty group (8.3%) compared to the non-watertight duraplasty group (29.2%, p=0.041). This finding aligns with previous studies highlighting the efficacy of watertight techniques in minimizing CSF leaks[1,2,3]. CSF leaks are associated with an increased risk of infections and prolonged hospital stays, emphasizing the importance of a watertight seal during duraplasty to minimize postoperative complications[4,5.] Studies by Chaurasia et al.[18] and Malhotra et al.19 have also reported similar reductions in CSF leak rates with watertight duraplasty techniques.

Although the watertight group had fewer postoperative infections (12.5%) compared to the non watertight group (25.0%), the difference was not statistically significant (p=0.271). This is consistent with mixed results from previous studies regarding the impact of duraplasty technique on infection rates[6,7]. The trend towards lower infection rates in the watertight group supports the hypothesis that a watertight seal reduces the entry of pathogens into the surgical site20. Larger sample sizes in future studies may provide more definitive conclusions on this outcome. Wound healing disturbances were less frequent in the watertight group (8.3%) compared to the non-watertight group (20.8%), though this difference did not reach statistical significance (p=0.214). These findings are in line with those of Yang and Wen21 and Prunet et al.[22], who reported better wound healing outcomes with watertight duraplasty. A secure dural closure may facilitate the natural healing process by preventing CSF leakage and reducing local tissue maceration[9].

The operative duration was significantly longer for the watertight duraplasty group (145 ± 25 minutes) compared to the non-watertight group (115 ± 20 minutes, p<0.001). This is consistent with previous research indicating that watertight techniques are technically more demanding and time-consuming[10,11 ,12]. The increased operative time should be balanced against the potential benefits of reduced CSF leaks and improved wound healing. Surgeons must weigh these factors when choosing the appropriate duraplasty technique for each patient.

Patients in the watertight group had a shorter average ICU stay (12.5 ± 4.2 days) compared to the non-watertight group (14.3 ± 5.1 days), though this was not statistically significant (p=0.187). However, the overall hospital stay was significantly shorter in the watertight duraplasty group (22.8 ± 6.3 days) compared to the non-watertight group (28.4 ± 7.2 days, p=0.027). These findings suggest that the benefits of watertight duraplasty may translate into faster overall recovery and earlier discharge, which can reduce healthcare costs and improve patient outcomes[13, 23]. Mortality rates were similar between the two groups, with 2 deaths (8.3%) in the watertight group and 3 deaths (12.5%) in the non-watertight group (p=0.642). Neurological outcomes, assessed using the Glasgow Outcome Scale (GOS) at 6 months post-surgery, also showed no significant difference between the two groups (mean GOS: 3.5 ± 1.1 vs. 3.3 ± 1.2, p=0.483). These findings are consistent with previous studies indicating that the choice of duraplasty technique does not significantly impact overall survival or long-term neurological outcomes[4,12,24].

Our results are consistent with international publications. For instance, a study by Hutchinson et al.4reported similar reductions in CSF leak rates and hospital stay durations with watertight duraplasty. Similarly, Jiang et al.[25] and Taylor et al.[24] found that watertight techniques reduced postoperative complications but increased operative time. Table 4compares our results with those from selected international studies, highlighting the global relevance of our findings.

Table 4: Comparison of Results from the Current Study and Selected International Publications

Outcome Measure CSF Leak Rate	Current Study		Hutchinson et al. (2016)4		Jiang et al. (2017)25		Taylor et al. (2015)[24]		al. (2020)
	WT	NWT	WT		NWT WT			NWT	WT
	8.3%	29.2%	10%	35%	7%	25%	9%	27%	8%

Chaurasia et 18 NWT 31%

Outcome Measure	Current Study		Hutchinson et al. (2016)[4]		Jiang et al. (2017)[25]		Taylor et al. (2015)[24]		al. (2020)
	WT	NWT	WT			WT		NWT	WT
Postoperative Infection Rate	12.5%	25.0%	11%	22%	12%	20%	14%	21%	13%
Wound Healing Disturbances	8.3%	20.8%	10%	23%	9%	22%	11%	24%	8%
Operative Duration (minutes)	145 ± 25	115 ± 20	150 ± 30	120 ± 25	140 ± 20	110 ± 15	145 ± 25	115 ± 20	150 ± 35
ICU Stay (days)	12.5 ± 4.2	14.3 ± 5.1	12 ± 5	15 ± 6	13 ± 4	14 ± 5	12 ± 5	15 ± 5	13 ± 4
Hospital Stay (days)	22.8 ± 6.3	28.4 ± 7.2	21 ± 5			28 ±		27 ± 7	24 ± 6
Mortality Rate	8.3%	12.5%	10%	15%	9%	14%	10%	13%	9%
Neurological Outcomes (GOS)	3.5 ± 1.1	3.3 ± 1.2	3.6 ± 1.0	3.2 ± 1.1	3.4 ± 1.1	3.3 ± 1.2	3.5 ± 1.2	3.2 ± 1.1	3.4 ± 1.0

WT = Watertight Duraplasty; NWT = Non-Watertight Duraplasty

This study has several limitations, including a relatively small sample size and the single-center design, which may limit the generalizability of the findings. Additionally, the longer operative duration associated with watertight duraplasty may increase the risk of other intraoperative complications not assessed in this study. Future multicenter studies with larger sample sizes and longer follow-up periods are needed to validate these findings and explore the cost-effectiveness of the different duraplasty techniques[4,6 ,7 ,10 ,23].

Conclusion

This prospective study has demonstrated that watertight duraplasty significantly reduces the incidence of cerebrospinal fluid (CSF) leaks and is associated with shorter hospital stays

compared
to non-watertight duraplasty in patients undergoing decompressive craniectomy (DC) for severe traumatic brain injury (TBI). Although the watertight technique resulted in a longer operative duration, it showed a trend towards fewer postoperative infections and better wound healing, albeit these differences were not statistically significant.

Our findings are consistent with international studies, indicating that watertight duraplasty is a viable option that can improve postoperative outcomes by minimizing complications. This reinforces the importance of meticulous dural closure in neurosurgical practice to enhance patient recovery and reduce healthcare costs.

However, the choice of duraplasty technique must consider individual patient factors and surgical context, particularly in emergent settings where operative time is critical. Future research with larger, multicenter cohorts and longer follow-up periods is necessary to further validate these findings and establish definitive guidelines for duraplasty techniques in DC procedures.

In conclusion, watertight duraplasty offers a promising approach to reducing postoperative complications in TBI patients undergoing DC, thereby contributing to better clinical outcomes and optimizing neurosurgical care.

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