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Main Subject [Neurosurgery]

Original Article

Comparative Study Between Gamma-Knife, Radiofrequency Ablation, and Microvascular Decompression in the Treatment of Trigeminal Neuralgia

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Abstract

Article information

Received: 19-05-2025

Accepted: 15-06-2025

DOI: 10.21608/ijma.2025.386921.2188.

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Citation: Taha AM, Hegab A, Al samoly HT, Dahshan SA. Comparative Study Between Gamma-Knife, Radiofrequency Ablation, and Microvascular Decompression in the Treatment of Trigeminal Neuralgia. IJMA 2025 July; 7 [7]: 5878-5884. doi: 10.21608/ijma.2025.386921.2188.

Background: Trigeminal neuralgia [TN] is a debilitating disorder that presents as severe, episodic facial pain, typically affecting the ophthalmic or maxillary branches of the trigeminal nerve. This study aimed to compare the clinical outcomes of three commonly used treatment modalities for TN: Gamma-Knife radiosurgery [GK], Radiofrequency ablation [RF], and Microvascular Decompression [MVD].

Patients and methods: This study was a single-center, retrospective, comparative study. It included 45 patients diagnosed with trigeminal neuralgia. Patients were randomly allocated into three treatment groups: Gamma-Knife [Group A], Radiofrequency Ablation [Group B], and Microvascular Decompression [Group C], with 15 patients in each group attending at Al-Azhar University Hospital in Damietta. The primary Outcome was the pain relief post-intervention which was measured using the Visual Analog Scale [VAS].

Results: We found a statistically significant reduction in the severity of pain from 7.4 ± 1.2 at the baseline to 1 ± 0.7 at 1 year postoperatively in the total population [P=0.001]. After 1 year, the degree of pain was improved in all studied groups which is better in group 2 and 3 than group 1 [P=0.03], however this difference is no significant clinically.

Conclusion: All three modalities are effective in managing pain and improving quality of life, MVD and RF ablation provide superior long-term outcomes compared to Gamma Knife.

Keywords: Trigeminal neuralgia; Decompression [MVD]; Gamma-Knife radiosurgery [GK]; Radiofrequency ablation [RF].

INTRODUCTION

Trigeminal neuralgia is a chronic pain disorder characterized by sudden, severe facial pain along one or more branches of the trigeminal nerve [1].

This condition is often linked to vascular compression of the trigeminal nerve root, leading to demyelination and ectopic neural discharges [2].

TN significantly impairs quality of life, often rendering patients unable to perform daily activities due to the unpredictable and intense nature of the pain [3].

First-line management of TN involves pharmacological therapy, particularly anticonvulsants such as carbamazepine or oxcarbazepine [4].

While effective in many cases, some patients experience inadequate pain control or intolerable side effects, necessitating consideration of surgical interventions for refractory cases. Surgical options include microvascular decompression, Gamma Knife radiosurgery [GKRS], and radiofrequency ablation [RFA], each with distinct mechanisms and outcomes [5].

MVD is a definitive surgical procedure aimed at relieving vascular compression of the trigeminal nerve, addressing the underlying pathophysiology of TN. Long-term studies have demonstrated that MVD offers significant and durable pain relief in many patients, with lower rates of recurrence compared to other surgical options[6]. However, the invasive nature of the procedure poses risks, including cerebrospinal fluid leakage and cranial nerve deficits [7].

GKRS, a non-invasive modality, delivers targeted radiation to the trigeminal nerve root, disrupting pain pathways without requiring open surgery. This technique is associated with a favorable safety profile and shorter recovery times. Recent studies highlight its efficacy in achieving pain relief, although the onset of relief is often delayed, and pain recurrence over time remains a concern. Additionally, a subset of patients may develop sensory complications, such as facial numbness, after the procedure [8].

RFA is a minimally invasive approach that involves creating thermal lesions in the trigeminal nerve fibers to interrupt pain conduction. It is particularly advantageous for patients who require immediate relief. Recent evidence underscores its effectiveness in managing TN, with many patients reporting rapid symptom resolution. However, its limitations include higher recurrence rates and sensory deficits [9].

The choice among these surgical interventions depends on various factors, including patient comorbidities, anatomical considerations, and personal preferences. Comparative studies have sought to elucidate the relative benefits and drawbacks of these techniques. For example, a recent meta-analysis reported that MVD is associated with the most durable pain relief, while GKRS and RFA offer lower procedural risks but higher recurrence rates. Additionally, GKRS is often preferred for older patients or those with significant comorbidities due to its non-invasive nature [10].

Despite advancements in the surgical management of TN, a lack of consensus remains regarding the optimal treatment approach, particularly for patients with refractory disease. A randomized clinical trial comparing MVD, GKRS, and RFA would provide robust evidence to guide clinical decision-making. Such a study would assess not only the efficacy and recurrence rates but also long-term safety, quality of life, and patient satisfaction associated with each intervention. This study aimed to compare the efficacy of Gamma-Knife, Radiofrequency Ablation, and Microvascular Decompression in alleviating pain in patients with trigeminal neuralgia.

PATIENTS AND METHODS

This study was a single-center, retrospective, comparative study. It included 45 patients diagnosed with trigeminal neuralgia. Patients were divided into three treatment groups: Gamma-Knife [Group A], Radiofrequency Ablation [Group B], and Microvascular Decompression [Group C], with 15 patients in each group attending at Al-Azhar University Hospital in Damietta. Our study was guided by the Helsinki declaration principals. Ethical approval was obtained from the institutional review board of Damietta faculty of medicine, Al-Azhar university.

The inclusion Criteria were: 1] Adults aged 18–70 years diagnosed with classical trigeminal neuralgia [ICHD-3 criteria]. 2] Patients with refractory symptoms despite medical management. 3] No prior surgical intervention for TN. The exclusion Criteria were: 1] Atypical trigeminal neuralgia or secondary causes such as tumors or multiple sclerosis. 2] Severe comorbidities precluding surgery. 3] Pregnancy or breastfeeding. 4] Previous cranial radiation or surgical intervention for TN

Data collection:

All participants were subjected to full history taking, general and local neurological examination, and routine laboratory investigations including a complete blood count, random blood glucose, a bleeding profile, and liver and kidney function tests. Clinical data were collected including the type and distribution of the pain, prescribed medications and dosages, preoperative time, and any unusual symptoms. Magnetic resonance imaging [MRI] of the cranial nerves was used to evaluate vascular compression. Visual analogue scale [VAS] was used for the assessment of pain severity [11].

The Barrow Neurological Institute [BNI] scale was used to assess postoperative numbness [12]. The primary outcome was the pain relief post-intervention which was measured using the Visual Analog Scale. The secondary outcomes included the presence of numbness, operative time, and complications.

Surgical technique

Group A – Gamma-Knife Radiosurgery: Patients underwent single-session Gamma-Knife radiosurgery targeting the trigeminal root entry zone. The dose delivered was ranged between 70–90 Gy.

Group B – Radiofrequency Ablation: Patients underwent percutaneous radiofrequency ablation under fluoroscopic guidance. Target temperature and duration was adjusted to achieve optimal pain relief while minimizing complications

Group C – Microvascular Decompression: Patients underwent craniotomy and decompression of the trigeminal nerve to relieve vascular compression. Standard neurosurgical protocols were followed.

Follow up: the patients were assessed on the first day postoperative then at 3 months, 6 months, 9 months and 12 months to assess the primary and secondary outcomes

Statistical analysis:

Statistical analysis was performed with SPSS statistical software, version 26 [IBM, Chicago, Illinois, USA]. The normality of the data was tested by the Kolmogrov-Smirnov test. Qualitative data was presented as numbers and percentages and were compared by the Chi square test, while quantitative data were presented as mean and standard deviations and were compared by the one-way ANOVA test. Paired parametric data were analyzed using the repeated measures ANOVA. As a result, the p-value was considered significant at the level of <0.05.

RESULTS

A total number of 45 patients with trigeminal neuralgia were included in our study. They were divided into three groups [15 patients per group]; group 1 included patients who underwent Gamma Knife, group 2 included patients who underwent Radio Frequency ablation, and group 3 included patients who underwent microvascular decompression. The mean age of the patients was 31.2 ± 5.2 years, and the percentage of females was higher than males [68.8% vs 31.1%]. The studied groups were comparable in terms of their age and gender [P=0.12, and 0.9 respectively] [Table 1].

According to the clinical data of the studied groups, the mean duration of symptoms was 1.3 ± 0.5 years with no statistically significant difference between the three groups [P =0.9]. The surgery duration was significantly longer in group 3 [987.7 ± 6.1 minutes] than group 2 [36.1 ± 4.6 minutes] and group 1 [21.5 ± 3.1 minutes] [P =0.001] [Table 2].

As regards the Pain assessment, we found a statistically significant reduction in the severity of pain from 7.4 ± 1.2 at the baseline to 1 ± 0.7 at 1 year postoperatively in the total population [P=0.001]. By comparing the three groups in terms of the pain improvement we found that at three months post operatively the three groups were relatively comparable in terms of pain which was 4.7 ± 1, 4.3 ± 1.2, and 5 ± 0.8 respectively [P = 0.1], however, after 6 months the degree of pain improvement was higher in group 2 and 3 than group 1 which still moderate [3.8 ± 1.7] in group 1 and mild in group 2 and 3 [1.7 ± 0.7, and 1.9 ± 0.7 respectively] [Table 3] [P=0.001]. After 1 year, the degree of pain was improved in all studied groups which is better in group 2 and 3 than group 1 [P=0.03], however this difference is no significant clinically [Table 3].

As regards the Numbness, we found a statistically significant reduction in the numbness in the three groups at all postoperative follow up periods [P=0.001 for all] [Table 4].

According to the complications, it was reported in group 2 and 3 only which included, four cases of bradycardia [2 in group 2 and 2 in group 3]. Two cases complained nausea and omitting [one in each group], four cases complained from dizziness [1 in group 2 and 3 in group 3], and four cases complained from fascial asymmetry [3 in group 2 and 1 in group 3] [Table 5].

Table [1]: Demographic data of the studied patients

Variables	Total [N=45]	Gamma Knife [N=15]	Radio Frequency [N=15]	Microvascular [N=15]	P value
Age [Years]					
Mean ± SD	31.2 ± 5.2	31.3 ± 5.4	30.8 ± 5.8	31.4 ± 5.1	0.12
Range	25 -40	22 - 40	25 - 40	24 – 40	
Gender					
Males	14 [31.1%]	4 [26.6%]	5 [33.3%]	5 [33.3%]	0.9
Females	31 [68.8%]	11 [73.3%]	10 [66.6%]	10 [66.6%]	
Comorbidities					
DM	8 [17.7%]	2 [13.3%]	3 [20%]	3 [20%]	0.6
No	37 [82.2%]	13 [86.6%]	12 [80%]	12 [80%]	

Table [2]: Clinical data of the studied patients.

Variables	Total [N=45]	Gamma Knife [N=15]	Radio Frequency [N=15]	Microvascular [N=15]	P value
Duration of symptoms					
Mean ± SD	1.3 ± 0.5	1.2 ± 0.5	1.3 ± 0.4	1.2 ± 0.5	0.9
Range	0.3 – 2	0.5 -2	0.4 - 2	0.3 – 2	
Surgery duration [min]					
Mean ± SD	48.4 ± 29.1	21.5 ± 3.1	36.1 ± 4.6	87.7 ± 6.1	0.001*
Range	15 - 99	15 – 27	29 – 45	79 - 99	

Table [3]: Pain assessment of the studied patients.

VAS	Total [N=45]	Gamma Knife [N=15]	Radio Frequency [N=15]	Microvascular [N=15]	P value
Preoperative					
Mean ± SD	7.4 ± 1.2	7 ± 1.2	7.4 ± 1.3	7.7 ± 1.1	0.3 [a]
No pain	0 [0%]	0 [0%]	0 [0%]	0 [0%]	0.4 [b]
Mild	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Moderate	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Severe	11 [24.4%]	5 [33.3%]	4 [26.7%]	2 [13.3%]	
Very Severe	34 [75.6%]	10 [66.7%]	11 [23.3%]	13 [86.6%]	
Post 3 months					
Mean ± SD	4.7 ± 1	4.7 ± 1	4.3 ± 1.2	5 ± 0.8	0.1 [a]
No pain	0 [0%]	0 [0%]	0 [0%]	0 [0%]	0.29 [b]
Mild	1 [2.2%]	0 [0%]	1 [6.7%]	0 [0%]	
Moderate	15 [33.3%]	5 [33.3%]	7 [46.7%]	3 [20%]	
Severe	29 [64.4%]	10 [66.7%]	7 [46.7%]	12 [80%]	
Post 6 months					
Mean ± SD	2.4 ± 1.4	3.8 ± 1.7	1.7 ± 0.7	1.9 ± 0.7	0.001* [a]
No pain	0 [0%]	0 [0%]	0 [0%]	0 [0%]	0.003* [b]
Mild	28 [62.2%]	3 [20%]	13 [86.7%]	12 [80%]	
Moderate	12 [%]	7 [46.7%]	2 [13.3%]	3 [20%]	
Severe	5 [11.1%]	5 [33.3%]	0 [0%]	0 [0%]	
Post 9 months					
Mean ± SD	1.6 ± 0.9	2.4 ± 1.1	1.3 ± 0.4	1.3 ± 0.5	0.002* [a]
No pain	0 [0%]	0 [0%]	0 [0%]	0 [0%]	0.02* [b]
Mild	40 [88.9%]	10 [66.7%]	15 [100%]	15 [100%]	
Moderate	4 [8.9%]	4 [26.7%]	0 [0%]	0 [0%]	
Severe	1[2.2%]	1 [6.7%]	0 [0%]	0 [0%]	
Post 1 year					
Mean ± SD	1 ± 0.7	1.4 ± 0.9	0.7 ± 0.2	0.8 ± 0.3	0.03* [a]
No pain	11 [24.4%]	1 [6.7%]	6 [40%]	4 [26.7%]	0.04* [b]
Mild	31 [68.9%]	11 [73.3%]	9 [60%]	11 [73.3%]	
Moderate	3 [6.7%]	3 [20%]	0 [0%]	0 [0%]	
Severe	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
P value	0.001* [c]	0.001* [c]	0.001* [c]	0.001* [c]	

a: One way ANOVA. b: Chi-square test. c: Repeated measure ANOVA.

Table [4]: Numbness assessment of the studied patients

Numbness	Total [N=45]	Gamma Knife [N=15]	Radio Frequency [N=15]	Microvascular [N=15]	P value
Preoperative					
Mean ± SD [BNI]	2.9 ± 0.9	3 ± 0.9	2.9 ± 0.9	2.8 ± 1	0.9 [a]
No	4 [8.9%]	1 [6.7%]	1 [6.7%]	2 [13.3%]	0.8 [b]
Mild	10 [22.2%]	3 [20%]	4 [26.7%]	3 [20%]	
Moderate	16 [35.6%]	6 [40%]	5 [33.3%]	5 [33.3%]	
Severe	15 [33.3%]	5 [33.3%]	5 [33.3%]	5 [33.3%]	
Post 3 months					
Mean ± SD [BNI]	1.4 ± 0.5	1.6 ± 0.5	1.4 ± 0.5	1.4 ± 0.3	0.5 [a]
No pain	23 [51.1%]	6 [40%]	9 [60%]	8 [53.3%]	0.53 [b]
Mild	22 [48.9%]	9 [60%]	6 [40%]	7 [46.7%]	
Moderate	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Severe	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Post 6 months					
Mean ± SD [BNI]	1.2 ± 0.4	1.3 ± 0.4	1.2 ± 0.4	1.2 ± 0.2	0.6 [a]
No	34 [75.6%]	10 [66.7%]	12 [80%]	12 [80%]	0.6 [b]
Mild	11 [24.4%]	5 [33.3%]	3 [20%]	3 [20%]	
Moderate	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Severe	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Post 9 months					
Mean ± SD [BNI]	1.1 ± 0.3	1.1 ± 0.3	1 ± 0.2	1.1 ± 0.3	0.8 [a]
No	40 [88.9%]	13 [86.7%]	14 [93.3%]	13 [86.7%]	0.78 [b]
Mild	5 [11.1%]	2 [13.3%]	1 [6.7%]	2 [13.3%]	
Moderate	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Severe	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Post 1 year					
Mean ± SD [BNI]	1 ± 0	1 ± 0	1 ± 0	1 ± 0	0.9 [a]
No	45 [100%]	15 [100%]	15 [100%]	15 [100%]	-
Mild	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Moderate	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
Severe	0 [0%]	0 [0%]	0 [0%]	0 [0%]	
P value [c]	0.001*	0.001*	0.001*	0.001*	

a: One way ANOVA. b: Chi-square test. c: Repeated measure ANOVA.

Table [5]: Complications of the studied patients

Complications	Total [N=45]	Gamma Knife [N=15]	Radio Frequency [N=15]	Microvascular [N=15]	P value [a]
No	37 [82.2%]	15 [100%]	11 [73.3%]	11 [73.3%]	0.08
Bradycardia	4 [8.8%]	0 [0%]	2 [13.3%]	2 [13.3%]	
Nausea / vomiting	2 [4.4%]	0 [0%]	1 [6.6%]	1 [6.6%]	
Dizziness	4 [8.8%]	0 [0%]	1 [6.6%]	3 [20%]	
Facial ecchymoma	4 [8.8%]	0 [0%]	3 [20%]	1 [6.6%]	

a: Chi-square test

DISCUSSION

Trigeminal neuralgia is a debilitating disorder that presents as severe, episodic facial pain, typically affecting the ophthalmic or maxillary branches of the trigeminal nerve. TN causes unilateral, intense electric shock-like pain along the trigeminal nerve divisions. Eating, chatting, brushing teeth, etc. can trigger it.TN affects 1 in 5,500 individuals globally, with higher rates in women and increasing age. The cause of TN is still debated. The most popular theory is that vascular compression causes TN [13].

While several treatment options exist, the choice of therapy remains individualized depending on the severity of symptoms, underlying pathology, and patient factors. This study aimed to compare the clinical outcomes of three commonly used treatment modalities for TN: Gamma-Knife radiosurgery, Radiofrequency ablation, and Microvascular Decompression. The results of this randomized clinical trial provide valuable insights into the relative effectiveness, safety, and postoperative outcomes of these interventions. One of the key findings in our study is the significant reduction in pain severity across all three treatment groups. The mean preoperative pain score of 7.4±1.2 decreased substantially to 1±0.7 at 1 year postoperatively [P = 0.001]. This substantial improvement in pain correlates with the findings of previous studies that have demonstrated the overall effectiveness of these treatments in alleviating TN-related pain [14–16]. The comparative analysis revealed a statistically significant differences between the three treatment groups at the 6-month and 1-year follow-ups. However, at 3 months, all three groups exhibited comparable pain relief [P = 0.1], suggesting that Gamma Knife, Radiofrequency ablation, and Microvascular Decompression provide similar short-term outcomes in pain management. At 6 months, patients in the RF and MVD groups reported greater pain improvement, with mild pain scores [1.7 ± 0.7 and 1.9 ± 0.7, respectively], while patients in the GK group still experienced moderate pain [3.8 ± 1.7]. At 1 year, although all groups showed improved pain scores, the RF and MVD groups maintained lower pain scores compared to the GK group [P = 0.03]. This suggests that while GK is an effective initial treatment, it may not offer the same long-term outcomes as RF or MVD. In a systematic review and metanalysis that was done by **Alizadeh *et al.*** [17] found that for TN that was resistant to drugs, 582 patients received MVD and 607 patients received GKS. The results showed that as compared to GKS, MVD was associated with more pain alleviation and less pain recurrence, which is in agreement with our findings. When comparing MVD to RF, **Li *et al.*** [13] discovered that MVD significantly reduced the requirement for a secondary operation following surgery [RR0.33, 95%CI 0.19 to0.56, I2=67%], suggesting that MVD is better than RF when it comes to pain recurrence. These findings are consistent with previous research indicating that MVD offers an 80% pain-free probability and a 10% recurrence rate over 10–20 years [18,19]. MVD success depends on TGN exposure throughout its course. It can be difficult to visualize the medial side of the root entrance zone, missing the problematic vascular and causing MVD failure. Failure was also linked to unshredded Teflon patches, free muscle grafts, and nerve compression from excessive Teflon use.

Habib *et al.* [20] and **Sindou *et al.*** [21] achieved an 80% success rate in treating patients, but they used more stringent criteria, such as requiring total pain relief and medication discontinuation to be considered a successful outcome. This study's success rate was thus comparable to theirs. In addition, 15.1% of patients reported treatment failure and 4.9% had mild residual pain that did not need medication. **Zhao *et al.*** [22] found that 70.2% of 1,070 patients in their RF series were pain-free after 10 years. Patients with initial poor medication response, atypical facial pain, and previous facial numbness were more likely to recur. The literature review agrees with our results in that, the MVD was superior to RF, and some even went so far as to suggest that RF should only be used in patients who were not surgical candidates or who refused invasive open procedures [13,20,23].

In our study, at 6 months, patients in the RF and MVD groups reported greater pain improvement, with mild pain scores [1.7±0.7 and 1.9±0.7, respectively], while patients in the GK group still experienced moderate pain [3.8±1.7]. At 1 year, although all groups showed improved pain scores, the RF and MVD groups maintained lower pain scores compared to the GK group [P = 0.03]. This suggests that GK gives its better efficacy on the long-term period. In a study by **Sato *et al.***[24] evaluated the short- and long-term outcomes of GK for TG found that the initial success rate [Pain relief] was 84.8% and the long-term success was 86% which is in agreement with our study findings.

In addition to pain relief, we also assessed the reduction in numbness, which is a common side effect of TN treatments. All three groups demonstrated significant improvement in numbness at all postoperative follow-up periods [P = 0.001], indicating that all three treatment modalities effectively reduce sensory dysfunction. At 3 months postoperatively the numbness was higher in GK followed by MVD and RF [60%, 46.7%, and 40%]. The incidence of numbness decreased at 6 months which was [33.3%, 20%, and 20% respectively]. After 9 months it was [13.3%, 13.3%, and 6.7% respectively] and at 12 months postoperatively there were no cases of numbness. Interestingly, although numbness was significantly reduced in all groups, the impact on facial sensation following Gamma Knife treatment may differ compared to the other two modalities. This is likely due to the non-invasive nature of GK, which targets the trigeminal nerve with focused radiation rather than physically disrupting the nerve or adjacent structures, as seen in RF and MVD [25]. As a result, patients who undergo GK may experience less long-term sensory impairment, but this may come at the expense of the treatment's overall long-term effectiveness, as shown in our pain relief findings. **Li *et al.*** [13] study, patients who were submitted for MVD complained lower incidence of fascial numbness in comparison to who did a RF [RR 0.27, 95% CI 0.19 to 0.39].

Another important aspect of our study was the comparison of surgical duration between the three groups. The MVD group had a significantly longer surgery duration [987.7±6.1 minutes] compared to the RF and GK groups [36.1±4.6 and 21.5±3.1 minutes, respectively] [P = 0.001]. This finding is in line with the literature, which reports that MVD is a more invasive procedure requiring longer operative times [1]. While MVD is associated with a higher rate of pain relief and lower recurrence rates, its invasiveness and prolonged recovery period must be weighed against its benefits. In contrast, both RF and GK are less invasive and have shorter procedure times, making them more suitable for patients who are not candidates for surgery or who prefer a quicker recovery time.

Safety is a critical concern when evaluating any medical procedure, and our study identified various complications in the RF and MVD groups. The complications observed included bradycardia, nausea, dizziness, and facial asymmetry. In contrast, no complications were reported in the GK group, which highlights the non-invasive nature of this treatment. This makes GK a highly attractive option for patients with contraindications to surgery or those who prefer a treatment with minimal associated risks. However, the lack of complications in the GK group must be considered alongside its relatively less durable long-term results, as demonstrated in the pain scores.

The findings of this study have important clinical implications. While all three treatments—Gamma-Knife, Radiofrequency ablation, and Microvascular Decompression—are effective in the management of trigeminal neuralgia, the choice of treatment should be individualized based on patient characteristics, including the severity of symptoms, overall health status, and preference for invasiveness. MVD remains the gold standard for long-term pain relief, but its invasiveness and longer recovery time may limit its suitability for some patients. In contrast, Gamma Knife offers a non-invasive alternative, albeit with potentially less durable outcomes. RF ablation strikes a balance between effectiveness and invasiveness but carries some risk of complications that must be considered. Further studies with larger sample sizes and longer follow-up periods are needed to confirm these findings and refine the optimal treatment approach for TN. Additionally, future research should explore the use of combination therapies and the identification of patient subgroups that are most likely to benefit from each treatment modality.

Conclusion: In conclusion, this study provides valuable insights into the comparative effectiveness and safety of Gamma-Knife radiosurgery, Radiofrequency ablation, and Microvascular Decompression for the treatment of trigeminal neuralgia. While all three modalities are effective in managing pain and improving quality of life, MVD and RF ablation provide superior long-term outcomes compared to Gamma Knife. However, the choice of treatment should be tailored to the individual patient, taking into consideration the severity of the disease, the patient's preferences, and the potential risks and benefits of each approach

Conflict of interest: All authors declare that they have no conflicts of interest related to the publication of this manuscript, including any affiliations with institutions, products, or entities mentioned in the study. Furthermore, the authors confirm that there are no conflicts of interest regarding products that may compete with those discussed in the manuscript.

Financial and non-financial activities and relationships of interest: None

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