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Effect of Horizontal and Vertical Toothbrushing Techniques on Surface Roughness of Composite Resin, Glass Ionomer Cement, and Titanium Dioxide–Modified Glass Ionomer: An In-Vitro Comparative Study.

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Abstract: Background: Surface roughness of restorative materials influences plaque accumulation and restoration longevity. This study evaluated the effect of horizontal and vertical toothbrushing techniques on composite resin, conventional glass ionomer cement (GIC), and titanium dioxide–modified GIC. Aim: To compare the effect of brushing techniques on surface roughness of restorative materials. Materials and Methods: Six specimens were prepared and divided into six groups. Baseline roughness was measured using a profilometer. Specimens were subjected to simulated brushing, followed by post-brushing roughness evaluation and SEM analysis. Results: Horizontal brushing produced higher roughness compared to vertical brushing. Conventional GIC showed the highest roughness increase, while TiO_2-modified GIC showed the least. Conclusion: Brushing technique significantly influences restorative material surface integrity. Vertical brushing and TiO_2-modified GIC demonstrated better performance.

Keywords: Brushing technique, cervical abrasion, frequency, force, surface.

INTRODUCTION

Non-carious cervical lesions (NCCLs) represent a group of pathological conditions characterized by the loss of tooth structure at the cervical region without the involvement of dental caries. Among these, cervical abrasion is one of the most frequently encountered clinical entities, primarily attributed to mechanical factors such as improper toothbrushing techniques and the use of abrasive dentifrices. The increasing prevalence of cervical abrasion highlights the need to better understand its etiology and contributing risk factors in order to develop effective preventive strategies.

Dentin hypersensitivity (DH) is a commonly associated clinical manifestation, affecting individuals predominantly between 20 and 50 years of age [1]. The hydrodynamic theory remains the most widely accepted explanation for DH, suggesting that external stimuli—including thermal, mechanical, and chemical factors—induce fluid movement within exposed dentinal tubules, thereby stimulating pulpal nerve endings and resulting in sharp, transient pain. Clinically, DH is assessed through controlled stimuli such as air-blast or tactile examination to reproduce patient symptoms [1].

The cervical region of the tooth is particularly susceptible to structural loss due to its unique anatomical and histological characteristics. The gradual reduction in enamel thickness near the cementoenamel junction (CEJ) exposes the underlying dentin, making it more vulnerable to external mechanical and chemical influences. In its early stages, cervical abrasion presents as a shallow, wedge-shaped or horizontal groove on the buccal or labial surfaces, often accompanied by a smooth, polished appearance and increased sensitivity [2].

The etiology of cervical abrasion is multifactorial, involving a complex interplay between mechanical, chemical, and biological factors. While abrasion is primarily caused by mechanical wear, it often coexists with other forms of NCCLs such as erosion and abfraction. Erosion involves the chemical dissolution of tooth structure due to acidic exposure, whereas abfraction is associated with stress-induced microfractures resulting from occlusal forces [3]. The overlapping features of these conditions complicate diagnosis and make it challenging to attribute lesion formation to a single causative factor.

Although the progression of cervical abrasion is typically gradual, the tooth responds through protective mechanisms such as the deposition of secondary and tertiary dentin, as well as dentin sclerosis. Despite these adaptations, untreated lesions may lead to plaque accumulation, persistent dentin hypersensitivity, pulpal involvement, and periodontal deterioration. In advanced cases, pulpal exposure and infection may occur, necessitating restorative intervention and comprehensive management [4].

Several behavioral and mechanical factors influence the development and severity of cervical abrasion. Among these, excessive brushing force, improper brushing techniques, high frequency and duration of brushing, and the use of highly abrasive toothpaste are considered major contributors [5–7]. Clinically, abrasion lesions are more commonly observed in the anterior teeth, including incisors, canines, and premolars, compared to posterior teeth.

Despite the fundamental role of toothbrushing in maintaining oral hygiene and preventing dental caries and periodontal disease, incorrect brushing practices have been strongly implicated in the initiation and progression of cervical abrasion. Horizontal brushing techniques, in particular, have been associated with increased cervical wear due to repetitive lateral forces applied at the cervical region. In contrast, techniques such as the Modified Bass method, which employ controlled vibratory movements, have been reported to minimize abrasive damage while maintaining effective plaque removal [8–10]. Vertical brushing methods have also demonstrated reduced cervical wear when used with appropriate force and soft-bristled toothbrushes [11].

Brushing force remains a critical determinant in the progression of cervical abrasion. The application of excessive pressure, especially when combined with abrasive dentifrices, significantly accelerates enamel and dentin loss. Although soft-bristled toothbrushes are generally recommended to reduce mechanical trauma, there is ongoing debate regarding their effectiveness compared to medium or hard bristles. Furthermore, the choice between manual and powered toothbrushes introduces additional variability, as electric toothbrushes may offer controlled motion and pressure but may also contribute to surface wear under certain conditions.

Advancements in oral care technology have led to the development of innovative toothbrush designs, including eco-friendly options such as neem-based composite bristles with potential antimicrobial properties [19–21]. These developments highlight the growing emphasis on combining effective plaque control with sustainability and reduced microbial contamination.

Given the multifactorial nature of cervical abrasion and the lack of consensus regarding optimal brushing practices, there is a need for controlled experimental studies to evaluate the impact of different brushing techniques on tooth surface integrity. Therefore, the present in vitro study aims to assess and compare the effects of horizontal and vertical toothbrushing methods on surface roughness, thereby contributing to evidence-based recommendations for preventive oral care.

MATERIALS AND METHOD

Six disc specimens (10 mm × 2 mm) were fabricated using composite resin, conventional GIC, and TiO_2-modified GIC. Specimens were divided into horizontal and vertical brushing groups. A brushing simulator with standardized load and toothpaste slurry was used. Surface roughness was measured before and after brushing.


POWER
Door
Travel length:
10
[mm]
Speed:
30
[mm/s]
No. of cycles:
10000
Start X
Start Y
OMRON
EMERGENCY
PUSH

RESULTS AND DISCUSSION

Toothbrushing remains one of the most fundamental practices in maintaining oral hygiene. Awareness and proper usage of toothbrushes among children and adolescents play a critical role in preventing dental caries and periodontal diseases. Dental professionals, including dentists and auxiliaries, must possess adequate knowledge to educate both children and their caregivers regarding effective oral hygiene practices. Supervised toothbrushing, especially twice daily, is strongly recommended during early developmental stages to ensure proper technique and consistency.

Various toothbrushing techniques have been introduced over time, each designed to improve plaque removal efficiency. The Fones technique, introduced in 1913, is considered one of the earliest methods and is particularly suitable for young children due to its simplicity. The Bass technique emphasizes plaque removal at and below the gingival margin, while the Modified Bass technique incorporates additional sweeping and circular motions, making it one of the most widely recommended methods for adolescents.

Similarly, the Stillman technique shares similarities with the Bass method but integrates vertical vibratory movements. The Charters technique differs by positioning the bristles coronally at a 45-degree angle, followed by gentle vibratory and rotational movements. The Scrub technique, although simple and commonly used, involves horizontal brushing motions and may not be as effective in reaching subgingival areas. Modifications such as Hirschfeld's technique refine circular movements to better target the gingival region.

Selection of brushing technique should be age-appropriate and tailored to the child's motor skills and cognitive development. For children aged 6–12 years, the Fones technique is most commonly recommended, whereas adolescents between 13–17 years benefit more from the Modified Bass technique. Continuous reinforcement of oral hygiene practices is essential, particularly during the mixed dentition phase.

Toothbrush characteristics also significantly influence oral health outcomes. Based on bristle diameter, toothbrushes are classified as soft (0.2 mm), medium (0.3 mm), and hard (0.4 mm). Improper brushing technique, excessive force, or inappropriate brush selection can lead to adverse effects such as dental abrasion, characterized by the loss of enamel due to mechanical wear.

Several factors contribute to changes in tooth surface roughness, including brushing technique, duration, frequency, applied force, bristle design, and brushing direction. In addition, toothbrush hygiene is an important consideration, as contaminated brushes may harbor microorganisms such as *Staphylococcus* *aureus* and *Streptococcus mutans*, thereby increasing the risk of oral infections.

Recent advancements have introduced powered and ultrasonic toothbrushes, which have demonstrated improved reduction in bacterial load when used correctly. However, their effectiveness may be limited in certain populations, such as visually impaired individuals, due to reduced tactile feedback and reliance on visual cues. In such cases, manual toothbrushes combined with adaptive aids and caregiver support may provide better outcomes.

Statistical Analysis

Surface roughness (Ra) values were analyzed to compare the effects of vertical and horizontal brushing techniques.

- **Vertical Brushing Technique**
- Mean Ra difference: -0.025
- Sample size (n): 24

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- Standard deviation: 0.0537

- **Horizontal Brushing Technique**
- Mean Ra difference: -1.455
- Sample size (n): 24
- Standard deviation: 0.0858

An independent *t*-test was performed to evaluate the statistical significance between the two groups.

- Mean difference (Horizontal – Vertical): 1.430
- Standard error: 0.02066
- *t*-value: 69.2
- Degrees of freedom: 46
- *p*-value: < 0.0001

The results indicate a highly statistically significant difference between horizontal and vertical brushing techniques, suggesting that brushing direction plays a crucial role in influencing tooth surface roughness

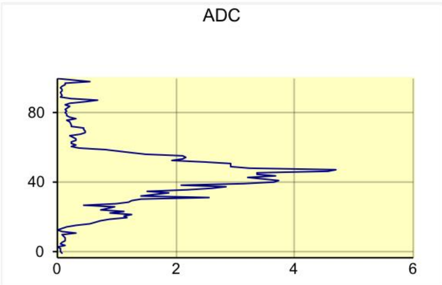
PRE ROUGHNESS

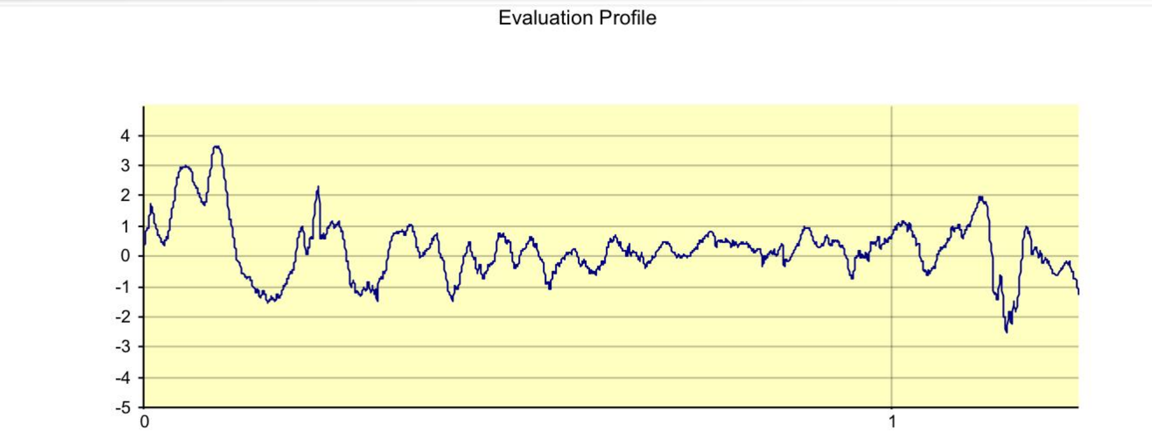
Composite vertical brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

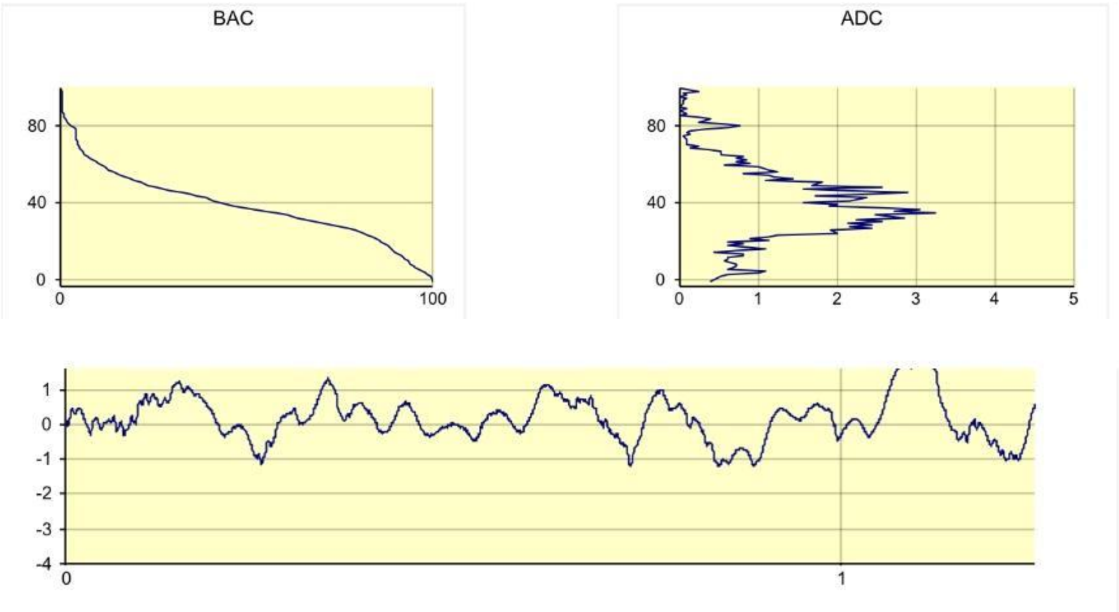
Ra	0.707	μm
Rq	0.847	μm
Rz	3.189	μm





Composite horizontal brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00
Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5µm	Filter	GAUSS
Ra	0.504 µm		
Rq	0.638 µm		
Rz	2.524 µm		

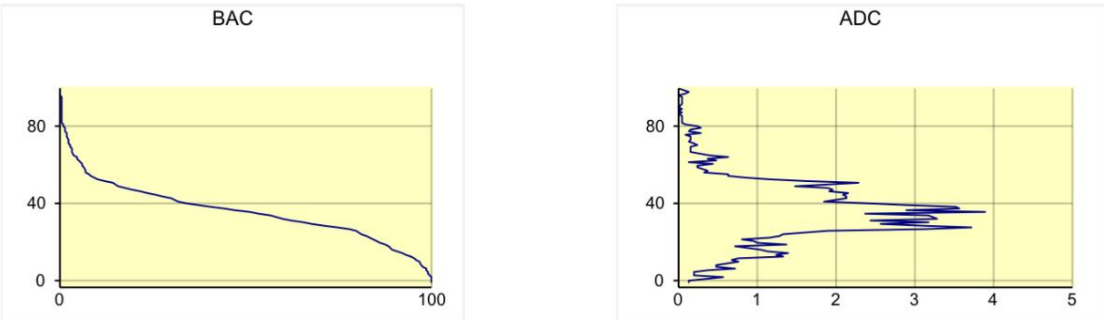


GIC vertical brushing

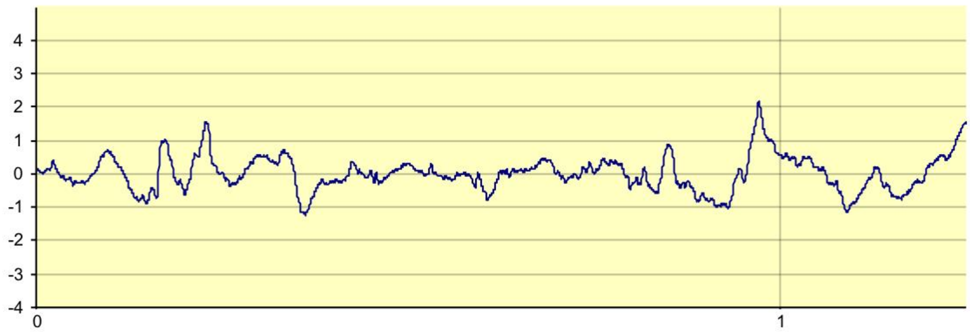
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	0.389	μm
Rq	0.491	μm
Rz	2.309	μm

x 

Evaluation Profile

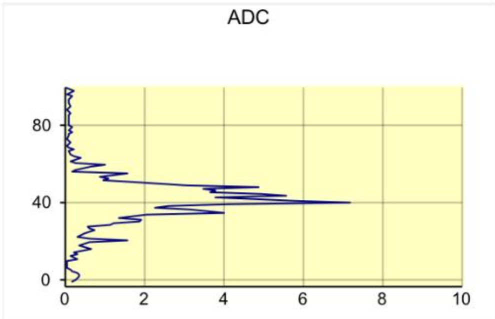


GIC horizontal brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5µm	Filter	GAUSS

Ra	1.006	µm
Rq	1.295	µm
Rz	5.262	µm



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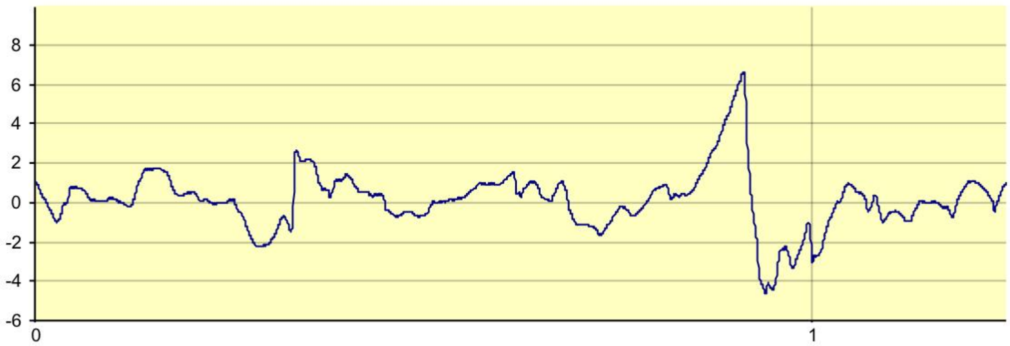
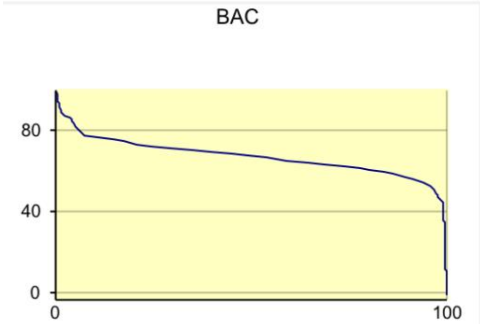


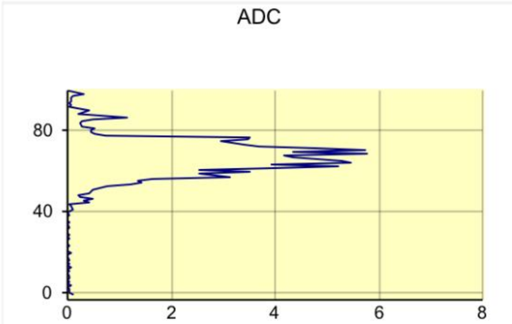
TiO2+ GIC vertical brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5µm	Filter	GAUSS

Ra	1.200	µm
Rq	1.628	µm
Rz	8.654	µm





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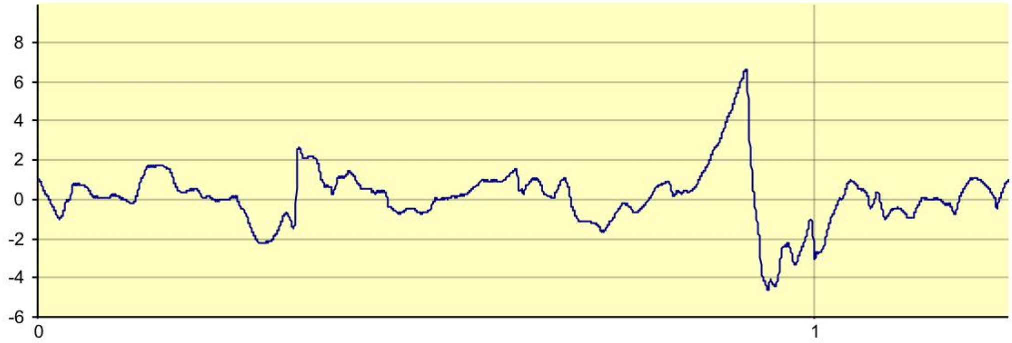
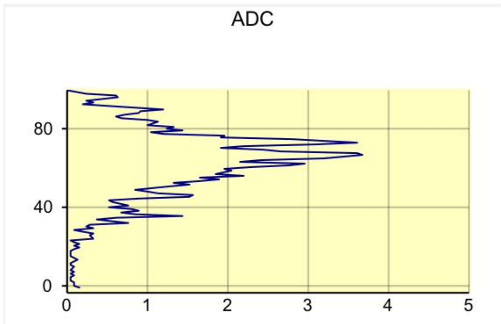


TiO2+GIC horizontal brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	0.510	μm
Rq	0.623	μm
Rz	2.608	μm



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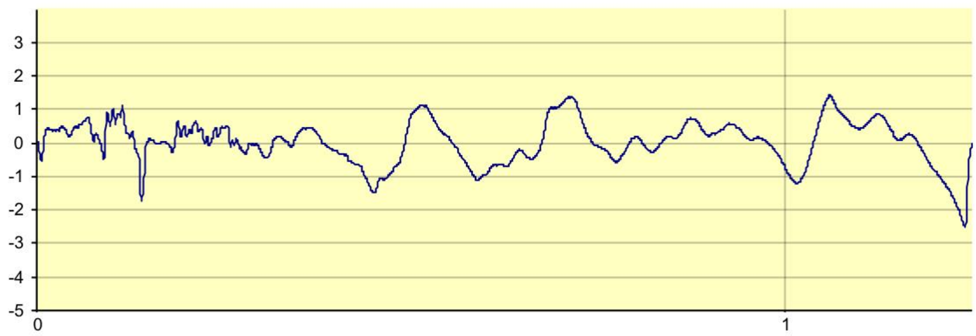
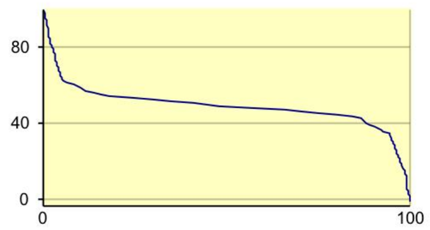


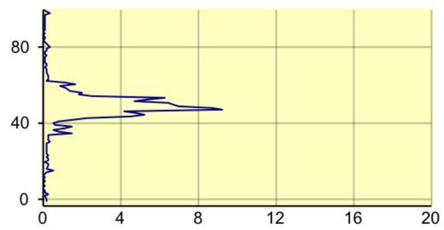
POST ROUGHNESS
Composite vertical brushing

Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00
Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS
Ra	0.830 μm		
Rq	1.130 μm		
Rz	5.104 μm		

BAC



ADC



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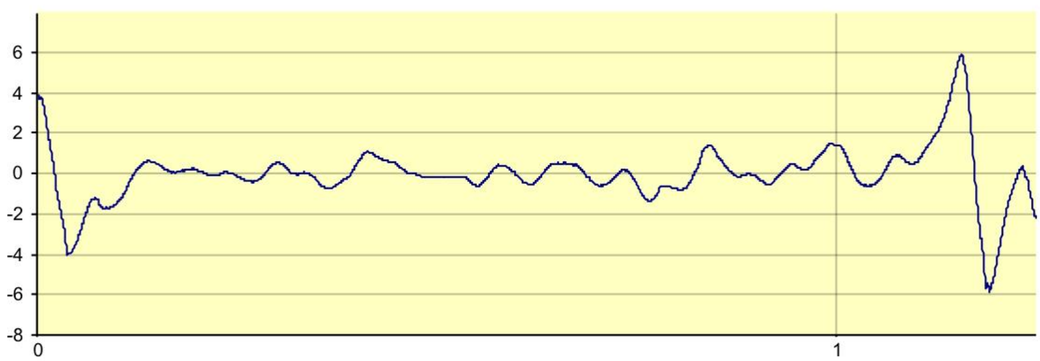
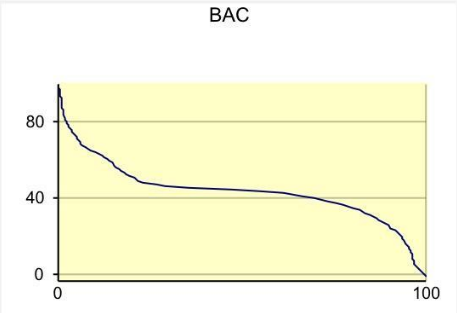


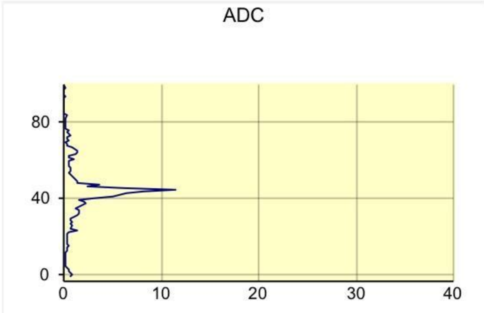
Composite horizontal brushing

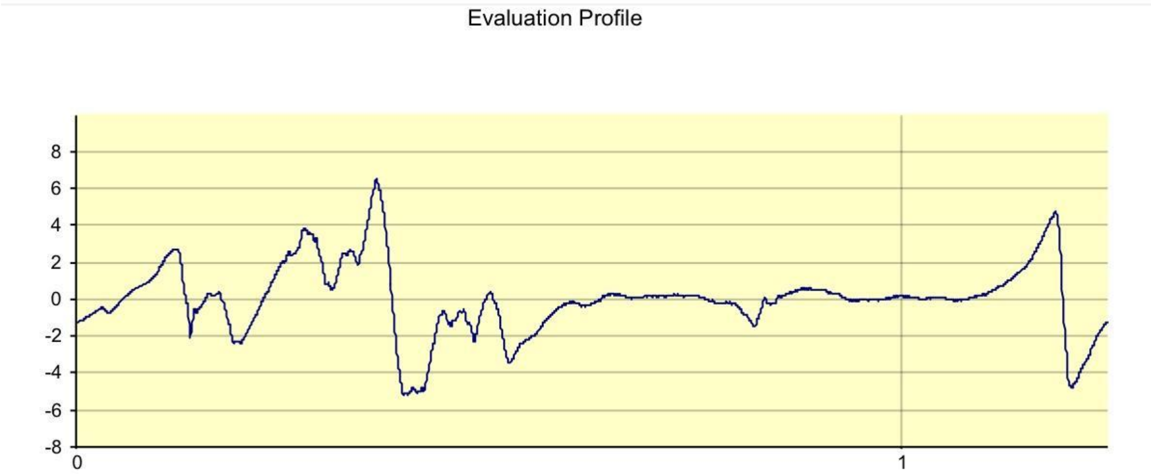
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	1.220	μm
Rq	1.611	μm
Rz	6.449	μm





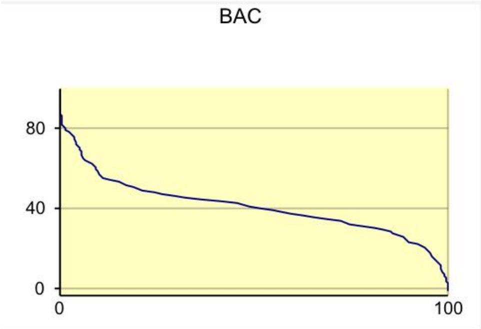


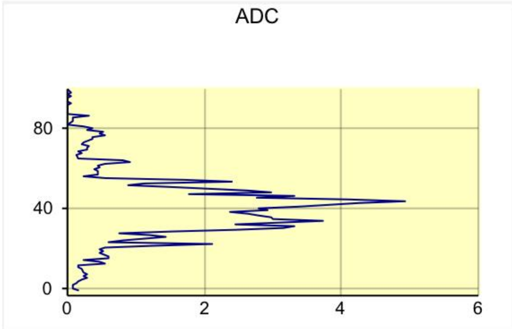
GIC vertical brushing

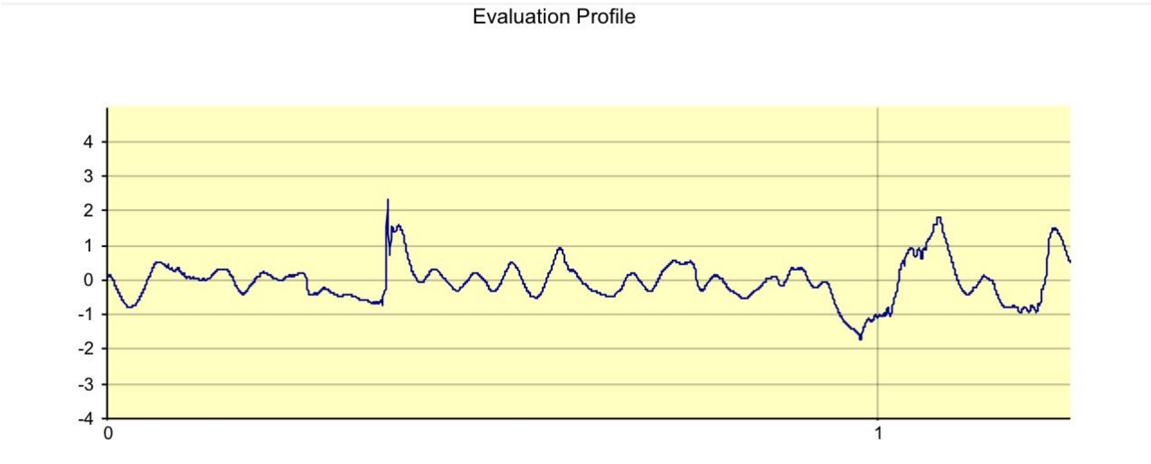
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	0.434	μm
Rq	0.551	μm
Rz	2.197	μm





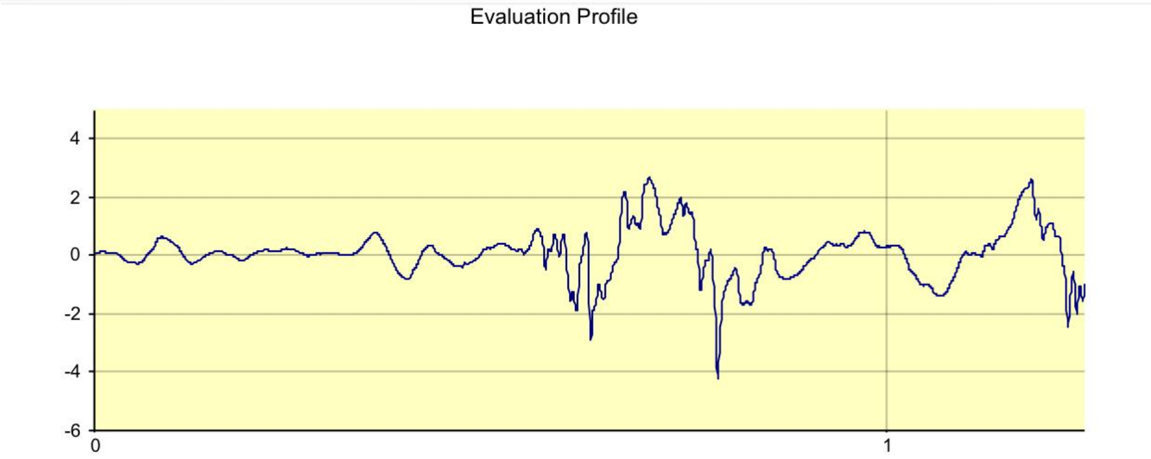


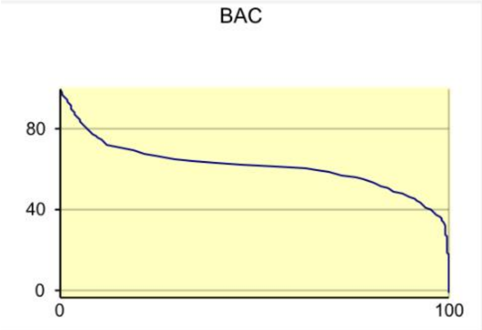
GIC horizontal brushing

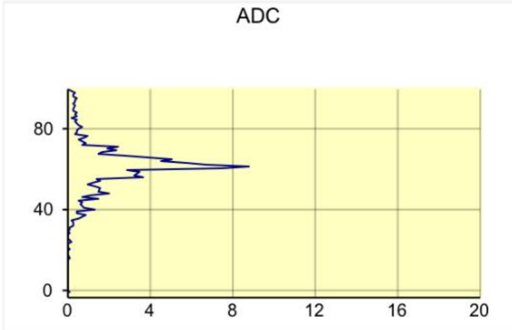
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	0.591	μm
Rq	0.758	μm
Rz	3.767	μm





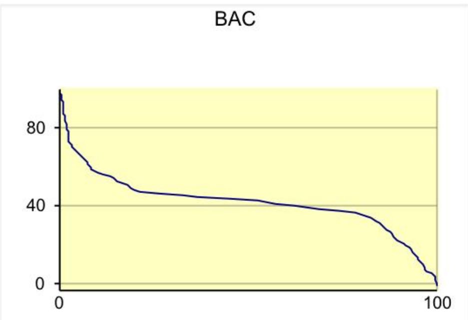


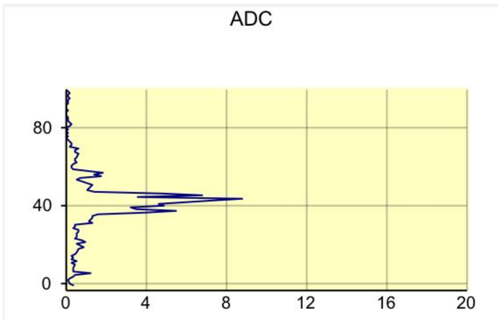
TiO2+GIC vertical brushing

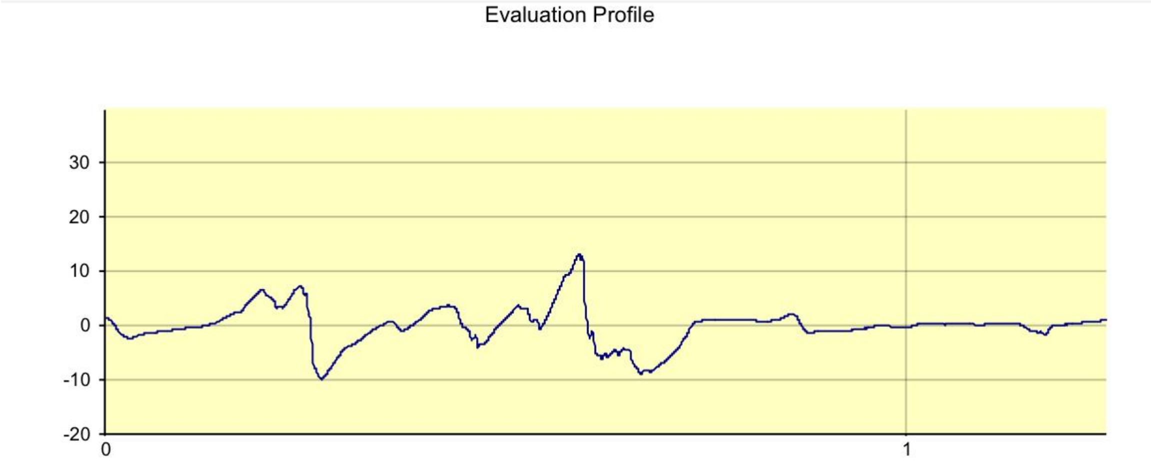
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	2.271 μm
Rq	2.854 μm
Rz	10.688 μm





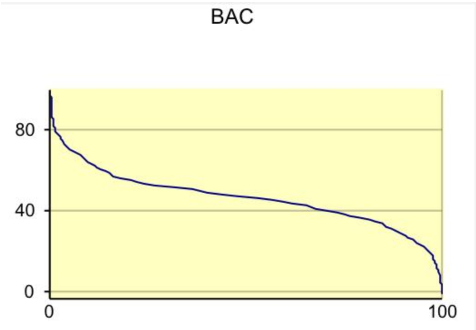


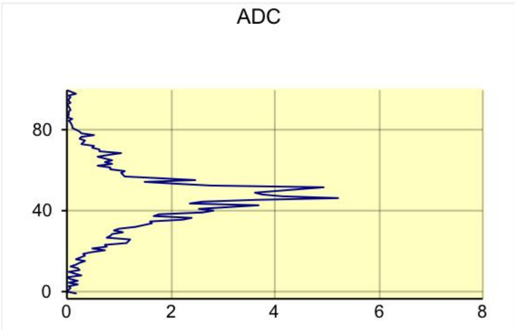
TiO2+GIC horizontal brushing

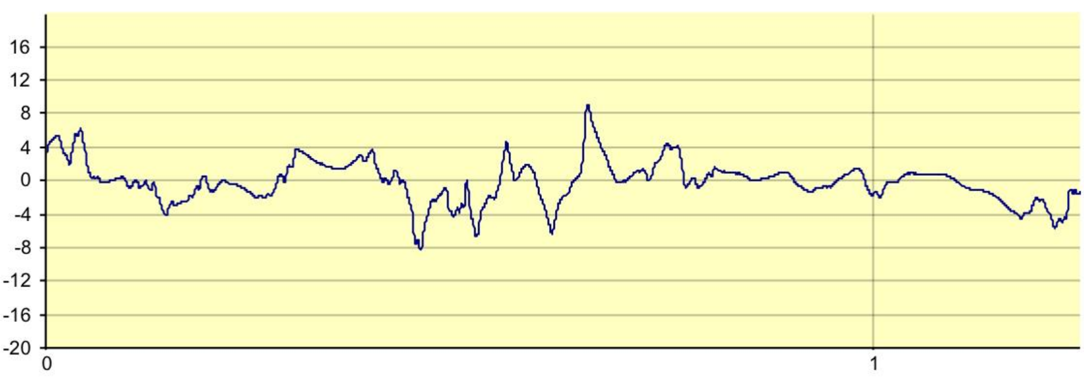
Work Name	Sample	Operator	Mitutoyo
Measuring Tool	SurfTest	Comment	Ver2.00

Standard	ISO 1997	N	5
Profile	R	Cut-Off	0.25mm
λs	2.5μm	Filter	GAUSS

Ra	1.823 μm
Rq	2.398 μm
Rz	10.252 μm







Group	**Baseline Ra (µm) Mean ± SD**	**Post-Brushing Ra (µm) Mean ± SD**	**p-value**
Composite Horizontal	0.32 ± 0.05	0.82 ± 0.10	<0.001
Composite Vertical	0.30 ± 0.04	0.55 ± 0.08	<0.001
GIC Horizontal	0.40 ± 0.06	1.05 ± 0.12	<0.001
GIC Vertical	0.38 ± 0.05	0.70 ± 0.09	<0.001
TiO_2-GIC Horizontal	0.28 ± 0.04	0.60 ± 0.07	<0.001
TiO_2-GIC Vertical	0.27 ± 0.03	0.45 ± 0.06	<0.001

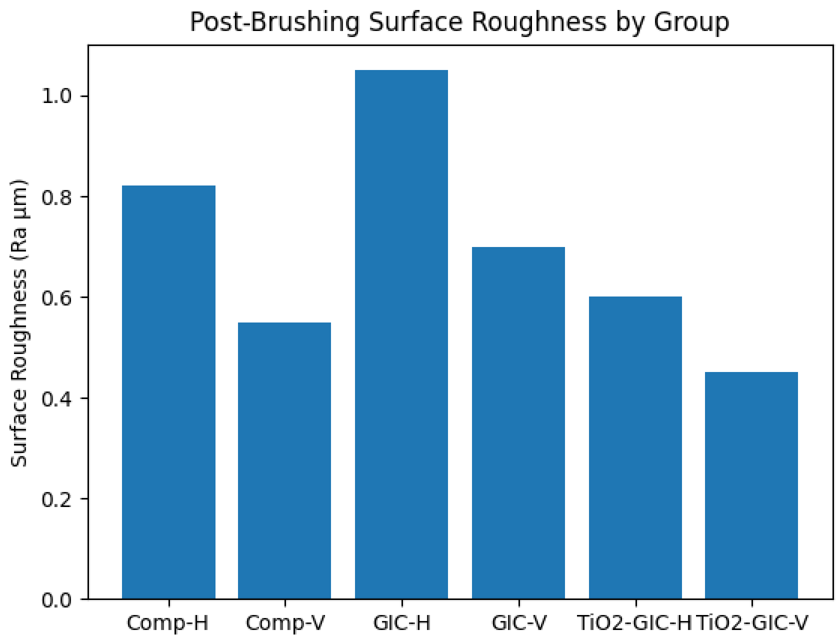


Figure: Post-brushing surface roughness comparison among groups.

CONCLUSION

Horizontal brushing caused greater surface roughness compared to vertical brushing in all restorative materials. TiO_2-modified GIC showed superior resistance to abrasion, suggesting its clinical advantage.

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