RESEARCH PAPER

Mechanical properties and Clinical Efficacy of flat-sided Nickel-Titanium rotary instruments: A narrative review

[1]Dr. Nikhil Harikrishnan, [2]Dr. Sneha R Bhat, [3]Dr. Jasmine Mary Anthony

[1]Lecturer, Yenepoya Dental College, Yenepoya (Deemed to be University), Mangalore, Karnataka, India. Orcid ID: 0000-0002-4537-8440

[2]Reader, Yenepoya Dental College, Yenepoya (Deemed to be University), Mangalore, Karnataka, India.Orcid ID: 0000-0001-8014-2372

[3]Lecturer, Yenepoya Dental College, Yenepoya (Deemed to be) University), Mangalore, Karnataka, India.Orcid ID: 0000-0002-3359-2183

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ABSTRACT

Aim. This review aims to compare the flat-sided nickel-titanium rotary instruments to conventional non-flat-sided instruments in terms of mechanical properties and clinical effectiveness in conventional endodontic practices.

Materials and Methods. A systematic search was conducted across multiple databases, including Scopus, PubMed, Web of Science, and Google Scholar. Additionally, a manual review of the grey literature was carried out to identify relevant articles. A thorough full-text review was conducted to verify eligibility after titles and abstracts were filtered against predetermined inclusion and exclusion criteria.

Results. Nickel-titanium files with a flat-sided design have, in recent years, drawn attention from both researchers and clinicians. These files, which were first introduced in 2015, feature a distinctive flat-sided shape and provide several benefits over their counterparts. Evidence suggests this modification significantly enhances mechanical flexibility and increases resistance to cyclic fatigue without compromising cleaning and shaping efficiency. However, the lack of standardization and the shortage of longer study protocols pose challenges to its widespread adoption.

Conclusion. Although flat-sided NiTi rotary instruments show great promise for improving canal morphology and reducing torsional stress, conflicting data about debris removal and biofilm eradication limit their clinical superiority. Additionally, there is conflicting evidence regarding their resistance to cyclic fatigue in the current literature. Thus, to confirm their long-term effectiveness and dependability, thorough in vivo studies and long-term clinical trials are essential.

Keywords: Nickel Titanium, Root canal preparation, Metallurgy, Biomechanical preparation, Cyclic fatigue.

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Author for Correspondence: Dr. Sneha R Bhat

Abbreviations:

NiTi: Nickel Titanium
PICO: Population, Intervention, Comparison, Outcome
FS: Flat-sided
NF: Non-flat
Rf: R-phase finish
As: Austenitic start
SEM: Scanning Electron Microscopy

INTRODUCTION

In endodontic treatment, root canal shaping is an important step. It affects the obturation and disinfection processes that follow. The main goals of root canal therapy are to maintain the original canal shape, eliminate the canal content, ensure the disinfection of the canal space, and create a continuous flow from the coronal access cavity to the root apex (1,2). Mechanical enlargement of the root canal permits irrigants to access the entire root canal system. This results in additional debridement via flushing and antibacterial properties (3). With the advent of Nickel-Titanium (NiTi) rotary instruments, endodontic procedures have become much simpler and use fewer instruments. This lowers the chance of iatrogenic errors while enabling quicker treatment (4). Notwithstanding their evident advantages, these instruments carry the risk of fracture without any obvious signs (5).

To address these issues, manufacturers have come up with several solutions, such as altering the design of the instrument, producing new NiTi alloys, and utilising novel activation kinematics (6). In recent years, rotary instruments featuring a flat surface on one side of the active blade have attracted attention among academics and clinicians. This design is intended to improve root canal preparation by increasing instrument flexibility and resistance to cyclic fatigue. The modified S-shaped cross-sectional design and reduced metal mass aim to make the instruments easier to guide through canal curvatures and less prone to breakage compared to conventional instruments (7-9). This narrative review's objectives are to outline the general characteristics of these innovative NiTi instruments and assess their clinical efficacy.

METHODS

Research question

The following question was formulated: "How do flat-sided nickel-titanium rotary instruments compare to conventional non-flat-sided instruments in terms of mechanical properties and clinical effectiveness in endodontic therapy?" To frame this question, a modified population, intervention, comparison, outcome (PICO) framework was used

Search strategy

A literature survey was conducted on flat-sided files across various databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search utilised MeSH keywords such as "nickel-titanium", "rotary files", "flat-sided", "biomechanical preparation", "Debridement ", "Instrument Design", "Cutting Efficiency", "Flexibility". In addition to database searches, a manual search was conducted to explore grey literature. Animal studies were excluded from the selection process. In addition, reference lists of relevant reviews and articles were searched manually to identify further reports. PRISMA flow diagram of the search process is provided in Figure 1.

Screening and study selection

The search results were processed by reference management software to remove duplicates. Following this, systematic screening of the article titles and abstracts was done by two independent reviewers. Studies that did not align with the focus of the review were excluded during this stage. Full-text articles were retrieved and assessed for eligibility based on the following criteria:

Inclusion Criteria:

- Only studies published from 2015 to 2025 were considered to ensure relevance.
- Original research articles, clinical trials, and systematic reviews focusing on flat-sided instruments were included.

Exclusion Criteria:

- Articles lacking empirical data, letters to the editor, and editorials were excluded.

In cases where any discrepancy between the two reviewers arose, a third senior reviewer was involved to resolve the disagreement.

RESULTS

The initial database search across PubMed, Scopus, and Web of Science found 49 records. After removing 12 duplicates, 37 unique studies are available for screening. The article selection process is shown in the figure (Figure 1). During the title and abstract screening phase, all 37 records were evaluated against the inclusion criteria. A total of 12 articles were excluded at this stage for not meeting at least one of the inclusion requirements. During the eligibility phase, the full text of all 25 articles was reviewed. Based on the established exclusion criteria, 16 studies were left out. Following the full-text evaluation, 9 studies met all inclusion criteria and were ultimately included in the qualitative synthesis.

Author for Correspondence: Dr. Sneha R Bhat

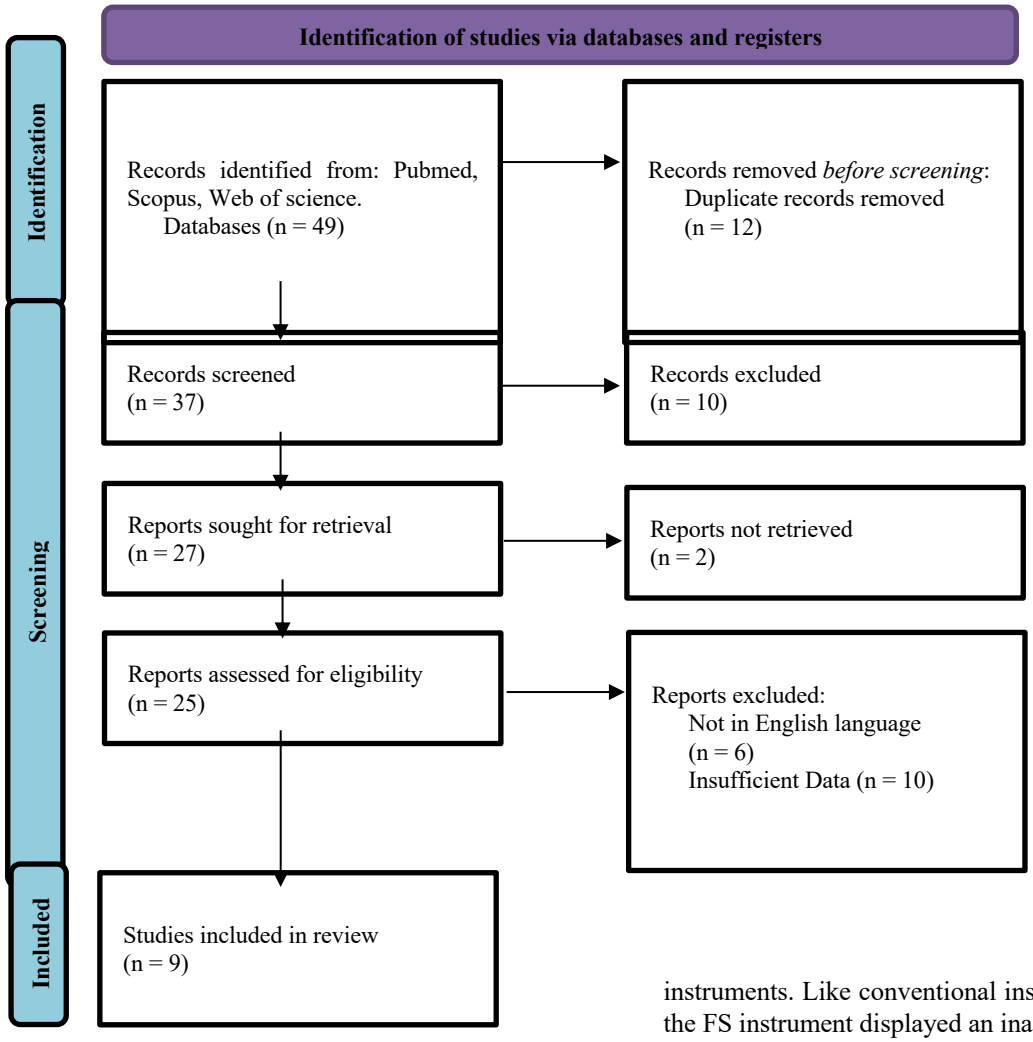

Figure 1: PRISMA flow diagram

DISCUSSION

Metallurgy

In the field of endodontics, the evolution of NiTi rotary instruments has led to various design modifications over the years. One such modification introduced was flat-sided (FS) instruments. The metallurgical composition of FS instruments is fundamentally similar to that of non-flat (NF) counterparts. Nearly equiatomic NiTi alloys are found in flat-sided instruments, whereas no measurable quantities of other metals were present(7). Nonetheless, studies have shown that there are notable variations in the phase transformation temperatures between the flat and non-flat-sided instruments. The R-phase finish (Rf) austenitic start (As) temperatures were found to be lower in the flat-side group than in the non-flat-side group (22.1°C and 11.6°C, respectively)(8).

DESIGN

From a macroscopic perspective, FS instruments were distinguishable from the NF instruments because they had a longitudinal flat surface on one side of the active blade. However, detailed observation reveals that the flat-side placement did not always line up with the active blade's long axis. Several fundamental design elements remain consistent with standard industry practices (9). Blade counts (n=8) and blade directions (clockwise) were nearly identical to the NF instruments. Like conventional instruments, the tip of the FS instrument displayed an inactive configuration. When subjected to Scanning Electron Microscopy (SEM) analysis, the presence of a flat side caused an incomplete S-shaped cross-section and asymmetry. SEM evaluation also highlighted dimpling marks on FS instruments, in contrast to the parallel markings usually found in the grinding process of NF instruments (7).

Mechanical performance

According to a 2023 study by Silva *et al.* (7), FS instruments maintained the maximum bending and buckling load and angle of rotation of NF instruments while having significantly lower values for time fracture, rotation to fracture, and maximum torque to fracture. The study also highlighted significant drawbacks, such as all FS instruments showed deformation following shaping procedures, whereas NF instruments showed no apparent surface changes. The authors ascribe these results to the presence of flaws on the flat surface brought on by the flattening process, as well as changes in their metallurgical characteristics. Ubaed *et al.* (10) in 2022 found that, in comparison to NF instruments, FS instruments had a lower cycle fatigue resistance. In contrast, files with flat sides performed better in terms of the number of cycles required to fracture. The flat design distributes the debris away from the flutes and onto the relieving region, which may reduce torsional stress on the instrument. This results in reduced screw-in effect and reduced friction against the canal walls.

Author for Correspondence: Dr. Sneha R Bhat

On the other hand, a different study by Gambarini *et al.* (11) in 2019 revealed that FS instruments had better cyclic fatigue than their counterparts. Because a flat design has lower mass, there is less blade engagement at one moment, which increases the flexibility of the instruments. This allows the instrument to navigate curvatures with less stress on the NiTi crystalline structure.

Shaping ability

Comparing the FS file systems with the NF prototypes, Di Nardo et al. (12) found that the former exhibited superior shaping capabilities. While preserving the original canal anatomy, FS design reduces the possibility of iatrogenic problems. By reducing the lateral stiffness of the file, the FS design minimises the forces that push the rotary instrument towards the walls of the root canal. This helps in preventing iatrogenic problems such as ledging, perforation, or zipping of the root canal.

Mogahed *et al.* (13) found that FS instruments did not outperform NF instruments in terms of cleaning and shaping. A key observation was that the FS instruments produced less debris than their counterparts. The flat side acts as a relief region that effectively captures the dentinal shavings. The Vertical blades are used to move the debris to these relief regions, which reduces debris accumulation around the file and improves cleaning efficiency.

The study conducted by Kaddoura *et al.* (14) in 2021 produced contradictory findings. Compared to FS instruments, NF instruments had substantially less canal deviation. The asymmetric cross-section creates an uneven distribution of stresses along the edge of the instrument. According to the authors, decentralised cutting efficiency might arise from an uneven or irregular distribution of stresses on the instrument due to the flat shape of the FS instruments.

Biofilm removal

In a microbiological assessment, Hamed *et al.* (15) compared the antimicrobial performance of FS instruments with their NF counterparts. The authors observed that FS instruments were much less effective in removing biofilms as compared to their NF equivalent, even though none of the evaluated file systems could totally eradicate the biofilms. The flat design creates debris accumulation that creates a buffer between the cutting edge and the dentin. The flat side results in uneven cutting of the surrounding walls, making it a time-consuming instrument with subpar biofilm removal capabilities.

Retreatment

Madarati *et al* (16) provided a critical comparison between different kinematic movements and instrument geometries on the removal of calcium silicate-based sealers. FS instruments in rotary motion had a significantly lower time for removal of calcium silicate-based sealers fillings as opposed to reciprocating instruments. This suggests that, by combining the continuous rotation and the modified geometry of FS instruments, the files were able to bore through the bulk of the sealer at a faster rate. However, these instruments were proven to be inferior in the efficiency of root canal filling material removal. While the FS instruments were able to remove at a faster rate, they were less effective in clearing the root canal filling materials from the root canal complexities. According to the authors, the cutting efficiency is adversely affected by debris accumulation inside the file flutes.

Future directions

The suggested benefits of the FS instruments remain largely contested, as recent empirical data present a contradictory landscape regarding their performance. The reduction in cross-sectional mass positively influences flexibility and stress distribution within the NiTi lattice. Instrument flattening, which reduces metal mass and flexibility, also unintentionally affects the buildup of debris surrounding the flutes. This localised compaction of dentinal shavings hinders not only the cutting efficacy but also increases the risk of apical extrusion. The efficacy of these files in clinical scenarios may be better understood with more research on their shaping capabilities, debris extrusion, and biofilm removal. There is a need for further research on how the modified cross-section of FS instruments affects the danger zones of the tooth and the prevention of iatrogenic errors. Furthermore, additional research into cycle fatigue and consequent instrument separation incidence and retrieval might be investigated. FS instruments create unique stress concentration points where microcracks can propagate, encountered in curved canals.

CONCLUSION

While the introduction of FS NiTi rotary instruments represents a significant change in design engineering, their overall clinical relevance remains a subject of ongoing debate. The flat-sided design offers potential for enhancing shaping ability and minimising torsional stress. However, current research indicates limitations that may hinder the widespread adoption of clinical practice. Evidence indicates decreased efficacy in biofilm removal, which potentially compromises the long-term success of the treatment. Limitations such as cyclic fatigue resistance and debris accumulation have also been highlighted. Additional in vivo and clinical investigations are required to thoroughly evaluate their long-term effectiveness.

Conflict Of Interest

The authors declare that they have no conflicts of interest.

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Not Applicable

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Author for Correspondence: Dr. Sneha R Bhat

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Declarations and Statements

Ethics Approval Statement

This article does not contain any studies with human or animal participants.

There are no human participants in this article, and informed consent is not required.

Consent to participate

Not Applicable

Consent for publication

Not Applicable

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Author for Correspondence: Dr. Sneha R Bhat