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# Structure Model Index Parameter for Shaping Effectiveness Difference Between Expanded and Reduced Taper Design Files: An in Vitro Study

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**ABSTRACT**

**Background and objectives:** To prepare root canal systems, the complex endodontic space must be shaped, enlarged, and disinfected. The taper design significantly influences the shaping efficacy of the instruments. This study attempts to assess the performance of decreased taper endodontic instrument systems (Bassi Logic .03 taper) compared to expandable heat-treated systems (XP-endo Shaper) in shaping simulated canal resin blocks in both straight and curved canals.

**Materials and methods:** Sixty simulated canal resin blocks have been used, comprising thirty blocks with straight canals and thirty blocks with curved canals featuring a 30° curvature. Each group was divided into three subgroups and pre-instrumentation photographs were obtained. Afterwards the resin blocks were prepared to an apical size of 25 utilizing various file systems: 1- reduced taper design (Bassi Logic .03 taper), 2- enlarged taper design (XP-endo Shaper), and 3- ProTaper Next (control group). Following instrumentation with the specified files, post-instrumentation photos were generated, and surface area and volume fluctuations were assessed utilizing AutoCAD software to determine the Structure Model Index (SMI). Statistical analysis was performed using non-parametric tests (Mann-Whitney Test and Kruskal-Wallis Test) with a significance level of $p<0.01$.

**Results:** The results of these investigations indicated that the ProTaper Next group exhibited the highest mean SMI, succeeded by the Bassi Logic. 03 taper group, whilst the XP-endo Shaper group demonstrated the lowest mean SMI relative to the other groups. In terms of the canal configuration, there is a statistically significant difference between straight canals and curved canals. In comparison to the curved group, the straight group displayed higher mean SMI, which suggests that the shaping effect in the straight group results in a more structured and possibly more conical canal morphology. On the other hand, the curved group demonstrates a more conservative shaping approach with less pronounced structural modification during the shaping process.

**Conclusion:** XP-endo Shaper group were more conservative and specific in reshaping the simulated root canals than other systems. The three systems used were respecting the internal anatomy of simulated root canals, other than non conservative shaping of the straight canals, even they were within acceptable limits.

**Keywords:** ProTaper Next, Bassi logic, XP-endo Shaper, Shaping ability, Structure Model Index

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## INTRODUCTION

Endodontics involves the preparation of root canals. Its goal is to disinfect and shape the root canal system by establishing a conical shape that tapers from the coronal to the apical end. Preparation of the root canal can be performed manually or by powered endodontic tools. Stainless steel instruments pose difficulties in the preservation of root canal anatomy. To overcome this, instruments composed of nickel-titanium (NiTi) alloys are currently employed in root canal shaping techniques.[1]

The utilization of nickel–titanium (NiTi, also known as Nitinol) alloys by Walia et al. in 1988 transformed the paradigm of root canal preparation procedures in endodontics. NiTi alloys exhibit flexibility that is 2–3 times greater than that of stainless steel. Moreover, a successful result of NiTi alloys are observed in the preparation of curved canals through continuous rotating motion. This is solely feasible because of the intrinsic characteristics of NiTi alloys pertaining to shape memory and super elasticity. These characteristics make NiTi rotary endodontic files comparatively safe for use in curved canals, resulting in a reduced incidence of canal aberration compared to stainless steel instruments.[2]

The preparation of root canal frequently results in a significant loss of tooth tissue, which may lead to fractures in root-filled teeth. For this reason, minimally invasive endodontics (MIE), which is defined by the elimination of a minimal volume of tooth tissue during root canal treatment, is currently popular.[3]

ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) instruments are composed of M-wire, a distinctive NiTi alloy produced via heat treatment procedure that purportedly enhances flexibility and resistance to cyclic fatigue. These instruments include varied regressive taper designs, A distinctive offset mass of rotation and a rectangular cross-section, which according to the manufacturer reduces instrument fatigue by reducing contact area with the canal walls.[4]

The XP-Endo Shaper (XPS; FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) works by continuous rotation movement that uses a one-file system. This file is snake-like and is triangular in cross-section. The apical diameter is 0.27 mm, also the taper is fixed at 0.01. Produced using MaxWire technology, this file possesses form memory and super elasticity. The file's martensite phase changes to austenite upon exposure to 35°C, and the taper increases to 0.04 based on the A phase's molecular memory. With a manual glide path of at least 15 ISO and a progressive rise of the apical size to 30 ISO, the file can begin shaping the canal. It's six-blade tip is called the booster tip. At least 30/0.04 is the final apical preparation that XP -endo Shaper achieves. When compared to alternative file systems, XP-endo Shaper demonstrated better cyclic fatigue performance.[5]

Bassi Logic files.03 taper (Bassi Endo, Belo Horizonte, Brazil) are endodontic instruments featuring tips that range from #15 to #50, with consistent tapers and varying cross-sectional designs based on the taper. The manufacturing process relies on the thermal treatment of CM wire, which exhibits superior arrangement of martensite crystal structure, recognized for it's ordered monocyclic form and enhanced flexibility relative to the austenite crystal structure. The substantial presence of this martensite structure renders these instruments devoid of shape memory, hence enhancing their flexibility and fatigue resistance.[6]

The manufacturer asserts that XP-endo Shaper instruments provide enhanced dentine preservation relative to traditional NiTi instruments.

Nevertheless, limited research has assessed the shaping efficacy and overall amount of dentine excised with MaxWire instruments;to date the findings are inconsistent, though some researches indicate enhanced preservation of tissues with MaxWire instruments, others denote increased dentine removal.

This research intended to assess the effectiveness of reduced taper system (Bassi Logic .03 taper) and MaxWire preparation system (XP-endo Shaper) in shaping simulated endodontic blocks.

ΔSMI, is a parameter that represents the difference in root canal cross section area after root canal preparation, especially for oval and circular cross-sectional designs.[7]

## METHODS

Sixty simulated canals, , thirty with straight canals and thirty with curved canals constructed from transparent polyester resin (Dentsply, Maillifer, Switzerland), were utilized; the diameter and tapering of all artificial canals corresponded to an ISO standard size 10 and taper 02 root canal instrument.

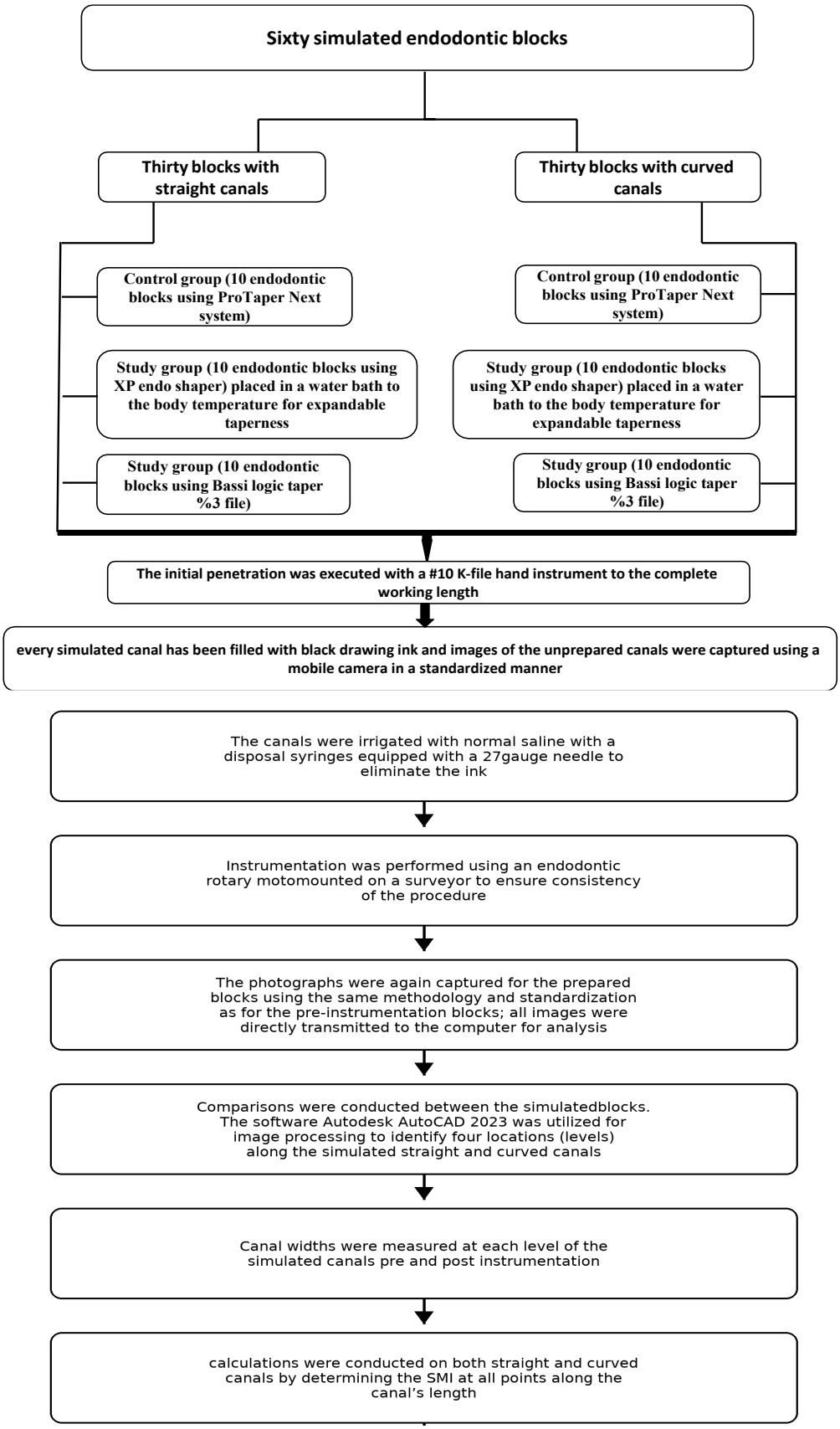


**Figure 1.** Illustrates a diagram showing the grouping of the samples and methodology


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Each group is subdivided into three subgroups:

1. Control group of 10 endodontic blocks utilizing the ProTaper Next system.
2. Study group of 10 endodontic blocks utilizing the XP endo shaper was immersed in a waterbath at body temperature to assess expandable tape.
3. Study group of 10 endodontic blocks with Bassi logic.03 taper.

The curvature of the curved canals was determined mathematically with a radius of 5.00 mm, producing an angle of 30° in accordance with Pruett's methodology.[8]

**Initial Imaging of Resin Blocks Before Shaping**

The initial penetration was executed with a #10 K -file hand instrument to the complete working length of 17 mm for straight canals and 13 mm for curved canals. Patency was confirmed using the same size following every sequence. Before preparation, every simulated canal was filled with black drawing ink and images of the unprepared canals were captured using a mobile camera in a standardized manner. The photograph was captured with the resin block positioned on a marked paper to guarantee consistent placement for each photograph taken. The mobile device used to capture the images was secured to a table jack, positioning the lens directly in front of the middle of the resin block (Figure 2). The captured photos were imported into AUTOCAD on the computer for measurement purposes. This process was reiterated for each block. Subsequent to picture acquisition, the canals were irrigated with normal saline using disposal syringes equipped with a 27-gauge needle to eliminate the ink, avoiding it's desiccation and obstruction of the canal.[9]

**Figure 2.** Photographing of resin blocks using a standard camera position

**Canal Preparation**

The resin blocks were secured in the water bath using a table jack (applicable solely to the XP-endo Shaper group). The location of the resin block was marked with an inedible pen on the table jack, and a bar level was positioned on each resin block to ensure accurate alignment within the table jack. Instrumentation was performed using an endodontic rotary motor Eighteeth (Changzhou, Jiangsu Province, China) mounted on a surveyor to ensure consistency of the procedure. The surveyor was positioned on a level surface, verified with a bar level, and the arm of the surveyor was perpendicular to this surface. The endo-motor handpiece utilized for instrumentation was oriented perpendicularly to the center of the canal orifice (Figure 3A, Figure 3B)

**Figure 3A, Figure 3B** Resin block instrumentation using dental surveyor with an endodontic engine is mounted in a water bath

**Group A (PROTAPER NEXT)**
A singleX2 file was utilized for preparation; with a tip size of 25, taper of 0.06, and a length of 25 mm. The instrument was passively placed into the root canal utilizing the endodontic motor with 300rpm speed and 2.5 N/cm torque as per the manufacturer's specifications. Irrigation was performed with 2 mL of normal saline between each stroke. A final irrigation of 5 mL normal saline was administered into the root canal subsequent to finishing of preparation.[10]

**Group B (XP-endo Shaper)**
Instrumentation was performed utilizing XP-endo Shaper (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) (#30/04) at 800 rpm speed and 1 N.cm torque applying moderate 3–5 strokes till the canal attained the full working length.[11]

**Group C (Bassi Logic.03 taper)**
Ten blocks from both straight and curved canals were prepared using Bassi Logic instruments (size 25, .0.03 taper) at 950 rpm and 2.0 Ncm, as indicated by the manufacturer. Three to five 'in and-out' pecking motions were executed, using little apical pressure and an amplitude of 3 mm, utilizing a delicate brushing technique on the canal. Between each peak motion, the canals were irrigated with 2ml of normal saline solution. Upon achieving the entire working length, the file is withdrawn while moving freely within the canal, followed by extensive irrigation of 5 ml with normal saline.[12]

The duration of preparation, quantity of irrigation, and lubricant (glycerin) utilized for all canals were identical. Each file is utilized solely a single time.

The prepared resin blocks were dried with paper point and left for 24 hours to ensure total dryness then, the blocks were filled with red ink by a disposable syringe along the entire working length. Photographs were again captured for the prepared blocks using the same methodology and standardization as for the pre-instrumentation blocks; all images were directly transmitted to the computer for analysis.[13]

The pre- and post-instrumentation photographs were compared utilizing the software Autodesk AutoCAD 2023 to identify four locations (levels) along the simulated straight and curved canals. Point A represented the most coronal level, whilst point D indicated the most apical level, with intervals of 4.25 mm between levels for straight canals and 3 mm for curved canals.[14] Fig 4A and Fig 4B illustrate diagrams that shows the superimposition of prior to and post-instrumentation photos at a certain height to demonstrate variance.

Subsequently, the SMI was determine at all points along the canal's length.

$$SMI = 6\ S'.V / S2$$

S represents the root surface area before to instrumentation; S' denotes the alteration in surface area resulting from instrumentation; and V signifies the root canal's initial volume before instrumentation.[7]

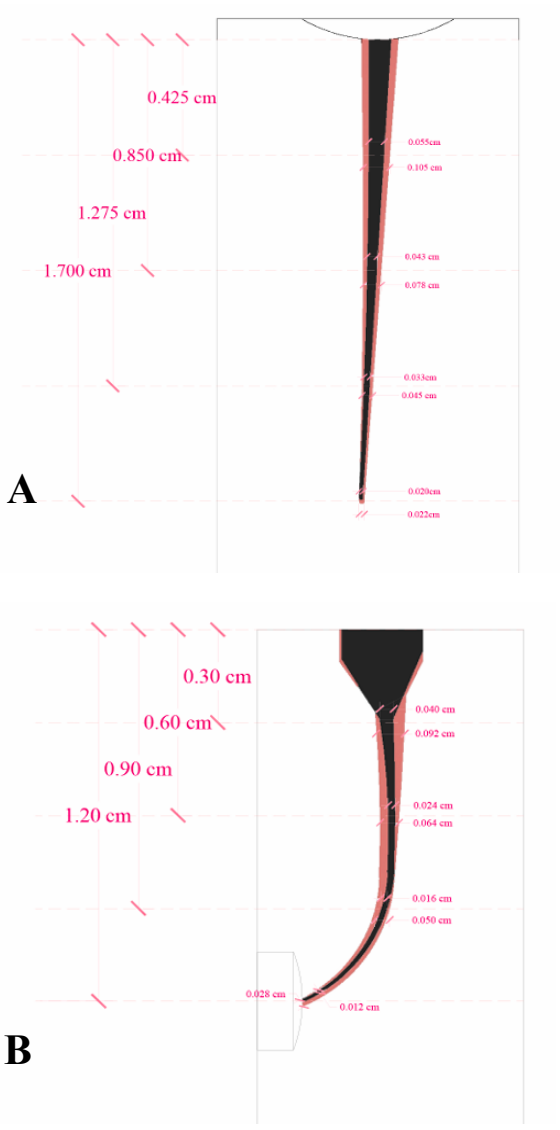


**Figure 4A, Figure 4B** Diagram illustrating the superimposition of prior to and post-instrumentation photos at a certain height to demonstrate variance


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**Statistical Analysis**

For statistical analysis, SPSS version 22.0 (SPSS Inc, Chicago, IL) employing non-parametric tests (Mann-Whitney and Kruskal-Wallis) with a significance threshold of ($p<0.01$) was used.

## RESULTS

**Test of Normality**

The normality test results for the Structure Model Index (SMI) in the straight and curved groups indicate that both distributions significantly deviate from normality. The Kolmogorov-Smirnov test (Straight: $p = 0.001$, Curved: $p = 0.000$) and Shapiro-Wilk test (Straight: $p = 0.000$, Curved: $p = 0.000$) both yield p-values below 0.05, rejecting the null hypothesis of normality. The straight group has a higher Shapiro-Wilk statistic (0.920), suggesting a closer approximation to normality compared to the curved group (0.507), which shows a more pronounced deviation. Given these results, non-parametric tests should be used for further statistical analysis of SMI in these groups, and Table 1 showed the Structure Model Index (SMI) values for different file systems in straight and curved root canals (Mean ± SD)

**Table 1.** Structure Model Index (SMI) values for different file systems in straight and curved root canals (Mean ± SD)

| Group | point | subgroup | SMI (Mean ± SD) |
|---|---|---|---|
| Straight | A | ProTaper Next | 0.0687 ± 0.0318 |
| | | XP-endo Shaper | 0.0437 ± 0.0030 |
| | | Bassi Logic. 03 taper | 0.0509 ± 0.0027 |
| | B | ProTaper Next | 0.0580 ± 0.0072 |
| | | XP-endo Shaper | 0.0390 ± 0.0029 |
| | | Bass Logic. 03 taper | 0.0413 ± 0.0030 |
| | C | ProTaper Next | 0.0369 ± 0.0024 |
| | | XP-endo Shaper | 0.0316 ± 0.0029 |
| | | Bass Logic. 03 taper | 0.0342 ± 0.0039 |
| | D | ProTaper Next | 0.0200 ± 0.0014 |
| | | XP-endo Shaper | 0.0193 ± 0.0016 |
| | | Bass logic. 03 taper | 0.0190 ± 0.0041 |
| Curved | A | ProTaper Next | 0.0407 ± 0.0037 |
| | | XP-endo Shaper | 0.0174 ± 0.0019 |
| | | Bass Logic. 03 taper | 0.0256 ± 0.0021 |
| | B | ProTaper Next | 0.0279 ± 0.0010 |
| | | XP-endo Shaper | 0.0119 ± 0.0013 |
| | | Bass Logic. 03 taper | 0.0378 ± 0.0493 |
| | C | ProTaper Next | 0.0207 ± 0.0019 |
| | | XP-endo Shaper | 0.0200 ± 0.0032 |
| | | Bass Logic. 03 taper | 0.0197 ± 0.0024 |
| | D | ProTaper Next | 0.0122 ± 0.0020 |
| | | XP-endo Shaper | 0.0081 ± 0.0017 |
| | | Bass Logic. 03 taper | 0.158 ± 0.0025 |

**Comparison Based on Group (Straight, Curved)**

Table 2 shows the Structure Model Index (SMI) values indicating statistically significant difference between the straight and curved groups ($p < 0.001$) based on the Mann-Whitney test.

**Table 2** Comparison of Structure Model Index (SMI) between straight and curved groups (Mann-Whitney Test)

| Group | N | SMI (Mean ± SD) | p-value |
|---|---|---|---|
| Straight | 120 | 0.0386 ± 0.0176 | < 0.001** |
| Curved | 120 | 0.0215 ± 0.0187 | |

[a] Used Mann-Whitney Test,
**Significant at level (p<0.01)

**Comparison Based on Subgroup (ProTaper Next, XP-endo Shaper, Bassi Logic. 03 taper))// Straight Groups**

In Table 3 the Kruskal-Wallis test compared SMI values among the straight groups (ProTaper Next, XP-endo Shaper, and Bassi Logic. 03 taper) with a p-value of 0.076, indicating that the differences in SMI among these groups are statistically not significant at the conventional threshold ($p < 0.05$) on SMI. Fig 5 demonstrates bar chart shows the comparison based on subgroups in the straight canals.

**Table 3.** Comparison of (SMI) of Straight Groups from (Pro Taper Next, XP-endo Shaper, Bassi Logic. 03 taper) using Kruskal-Wallis Test)

| Group | N | SMI (Mean ± SD) | p-value[a] |
|---|---|---|---|
| ProTaper Next | 40 | 0.0459 ± 0.0247 | 0.076 |
| XP-endo Shaper | 40 | 0.0334 ± 0.0097 | |
| Bassi Logic.03 taper | 40 | 0.0364 ± 0.0122 | |
| Total | 120 | 0.0386 ± 0.0176 | |

[a] Used Kruskal-Wallis Test

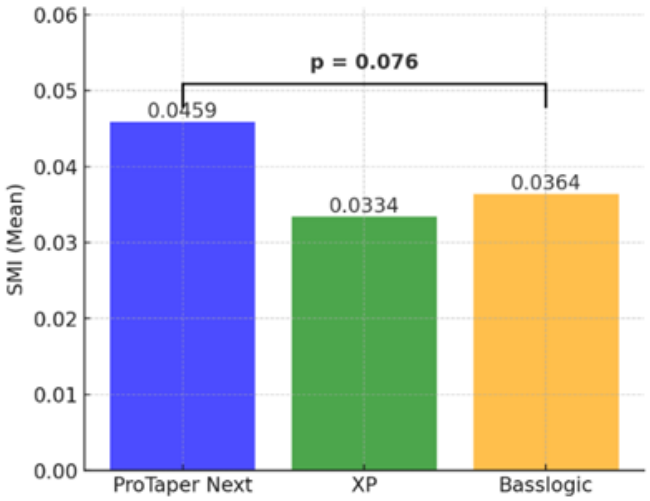


**Figure 5.** Comparison of (SMI) of straight groups from (ProTaper Next, XP-endo Shaper, Bassi Logic. 03 taper) (using Kruskal-Wallis Test)

**Comparison Based on Subgroup (ProTaper Next, XP-endo Shaper, Bassi Logic. 03 taper))// curved groups**

The Kruskal-Wallis test compares SMI values among the curved groups (ProTaper Next, XP-endo Shaper, and Bassi Logic. 03 taper) reveals significant difference statistically ($p < 0.001$), indicating the shaping effectiveness differs among these systems (Table 4).

**Table 4.** Comparison of (SMI) of curved groups from (ProTaper Next, XP-endo Shaper, Bassi Logic. 03 taper) using Kruskal-Wallis Test)

| Group | N | SMI (Mean ± SD) | p-value[a] |
|---|---|---|---|
| ProTaper Next | 40 | 0.0254 ± 0.0177 | < 0.001** |
| XP-endo Shaper | 40 | 0.0143 ± 0.0153 | |
| Bassi Logic. 03 taper | 40 | 0.0247 ± 0.0252 | |
| Total | 120 | 0.0215 ± 0.0187 | |

[a] Used Kruskal-Wallis Test,
**Significant at level (p<0.01)


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**Comparison Based on File System**

The Kruskal-Wallis test in Table 5 demonstrated significant differences in SMI values across the three groups (p = 0.001),. Fig 6 demonstrates bar chart shows the comparison based on different file groups.

**Table 5.** Kruskal-Wallis test showing SMI across three file groups

| Group | N | SMI (Mean ± SD) | p-value [a] |
|---|---|---|---|
| ProTaper Next | 80 | 0.0356 ± 0.0216 | 0.001** |
| XP-endo Shaper | 80 | 0.0239 ± 0.0159 | |
| Bassi Logic. 03 taper | 80 | 0.0305 ± 0.0206 | |
| Total | 240 | 0.0300 ± 0.0202 | |

[a] Used Kruskal-Wallis Test,
**Significant at level (p<0.01)

The Tukey HSD post-hoc test revealed a statistically significant difference in SMI between ProTaper Next and XP-endo shaper (mean difference = 0.0117, p = 0.001), with ProTaper Next exhibiting a higher mean SMI. The comparisons between ProTaper Next and Bassi Logic. 03 taper (p = 0.226) and between XP-endo Shaper and Bassi Logic. 03 taper (p = 0.082) were not statistically significant, as their p-values surpassed the 0.05 threshold and their confidence intervals encompassed zero. The results suggest that the total group difference found in the Kruskal-Wallis test is mostly attributable to the significantly elevated SMI in the ProTaper Next group compared to XP -endo shaper (Table 6).

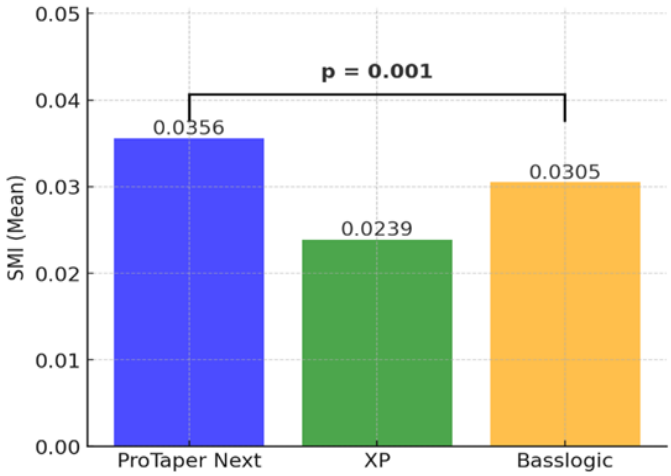


**Figure 6.** Bar chart demonstrating SMI values across the three file groups

**Table 6.** Multiple Comparisons of SMI among file systems using Tukey HSD

| Comparison | Mean Difference (I-J) | Std. Error | p-value | 95% Confidence Interval (Lower - Upper) |
|---|---|---|---|---|
| ProTaper Next vs. XP-endo Shaper | 0.0117 | 0.0031 | 0.001 | 0.0045 - 0.0190 |
| ProTaper Next vs. Bassi Logic. 03 taper | 0.0051 | 0.0031 | 0.226 | -0.0022 - 0.0124 |
| XP-endo shaper vs. Bassi Logic. 03 taper | -0.0066 | 0.0031 | 0.082 | -0.0139 - 0.0006 |

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## DISCUSSION

The efficacy of endodontic therapy depends on critical elements, including complete root canal system cleansing and proper instrumentation. Instrumentation directly impacts dentin thickness, hence affecting the fracture resistance of the root.[15,16] Maintaining an adequate thickness of dentin is crucial for enhancing fracture resistance and the overall strength of treated teeth.[17]

While there are several ways to measure endodontic instrument's root canal shaping capability, this study used a prefabricated resin block model to compare the amount of resin removed from canals before and after instrumentation. Four distinct levels were evaluated for area discrepancies. Endodontic instruments which induce fewer morphological changes in root canals and show smaller resulting difference area between canals before and after instrumentation, are shown to improve fracture resistance.[18]

Due to varying hardness and abrasion properties of acrylic resin compared to root dentin, some suggest that the utilization of resin blocks is problematic.[19]

In the current investigation, simulated blocks were used to standardize the design (length and curvature) to be used for all tested instruments which is difficult to see in extracted teeth. Second, direct measurements can also be used to evaluate the final canal instrumentation. Finally, the hardness of dentin varies by up to 25% when we use extracted teeth, especially when they come from several donors. This can hinder root canal instrumentation studies by making it difficult to compare samples due to inherent variability.[20] Although micro computed tomography imaging is considered the most precise way to assess the instrumentation of canals using NiTi instruments, utilizing super imposition is a commonly used and appropriate method to examine the shaping effects of instruments inside the canals.[21] The shaping efficacy of Ni-Ti files can be influenced by numerous aspects, including alloy microstructure, taper, cross-sectional geometry, motion, and system composition. The microstructure of Ni-Ti wire has three phases: austenite, martensite, and R-phase. The Ni-Ti alloy exhibits strength and rigidity in the austenite phase, while demonstrating flexibility and ductility in the martensite phase.[22]

The current study evaluated the shaping efficacy of ProTaper Next, XP-endo Shaper, and Bassi Logic. 03 taper in resin straight and curved canals. The results demonstrated a statistical significant difference in SMI values among the three study groups ($p = 0.001$), showing that the distribution of SMI scores varies between the groups. The ProTaper next group exhibited the highest mean SMI, succeeded by Bassi Logic. 03 taper, whereas the XP-endo Shaper group recorded the lowest mean SMI. XP-endo Shaper is the market's only MaxWire alloy-based instrument. The instrument's unique metal type has various advantages. Despite the differing metals and constructions of XP-endo Shaper and ProTaper Next, both devices exhibit spiral movement. The manufacturer asserts that XP-endo Shaper may grow from 0.01 to 0.04 taper in root canals. The expansion rate can be adjusted to the morphology of the root canal. Likewise, by employing rotational offset mass and oscillatory motion, ProTaper next can excise more amounts of tissue than instruments of comparable tip size.[23]

Earlier studies indicated that the ProTaper Next file with a 0.06 taper may excise an equivalent volume of dentin as other instruments with a 0.08 apical taper due to its asymmetric design.[24]

An investigation by Öztürk et al. comparing the shaping effectiveness of ProTaper Next with XP-endo Shaper using Cone Beam Computed Tomographic Analysis discovered that neither the mean increase of the prepared area nor the mean increase of the prepared outline in wide root canals showed any statistically significant alterations.[25] A study by Lima et al. used microcomputed tomography (micro-CT) analysis to evaluate the shaping effectiveness of an expandable heat-treated system (XP-endo Shaper) and a reduced taper endodontic instrument system (Bassi Logic.03 taper) in shaping canals of mandibular molars. The Reciproc system served as the benchmark for comparison. For both mesial and distal roots, there was no discernible variation in the percentage of dentine removed between Bassi Logic.03, XP-endo Shaper and Reciproc.[12]

The outcomes of both researches are not in line with current investigation which maybe attributed to difficulty in simulating the clinical scenarios. Standardizing extracted human teeth regarding canal diameter, length, curvature in terms of angle and radius, and variation in dentin hardness


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among different donors was the principal issue of these studies.

It had been determined that rotary instruments with identical tip sizes and tapers yield comparable dentin removal, while instruments with bigger tapers and the same tip size result in increased dentin removal.[25]

The results of current study can be justified by varying tapers of ProTaper Next, XP-endo Shaper and Bassi Logic .03 files despite thee identical tip sizes. Bassi Logic .03 has reduced taper, while XP-endo Shaper enlarges and adapts to the root canal wall, which may in turn increases contact area between the file and root canal wall. In addition, ProTaper Next instruments have broader taper size.[12]

Structural model index variations between straight and curved groups were also compared. A statistically substantial disparity was shown between straight and curved groups the straight group exhibited a higher mean SMI compared to the curved group, suggesting that the shaping effect in the straight group results in a more structured and possibly more conical canal morphology, whereas the curved group demonstrates a more conservative shaping approach with less pronounced structural modification.

A research study conducted by Alexander et al. evaluated SMI between straight and curved root canals in both extracted human teeth and simulated endodontic blocks. The results showed no significant difference in SMI between straight and curved canals in both groups(7). This discrepancy might be due to the difference in the evaluation methodology. the samples were evaluated with the aid of Microcomputed Tomography while in our study the block measurements are performed by using AUTOCAD software program.

For several reasons, the results of this research should be carefully considered. First A three-dimensional canal was evaluated in two dimensions. Second, there is a variation in dentin hardness between resin blocks and human teeth. Third, when compared to human dentin, resin blocks showed different thermal properties. Even with these limitations, simulated resin blocks are considered an appropriate experimental tool for studies investigating shaping ability as they limit anatomical variations present in natural teeth.[5]

## CONCLUSION

XP-endo Shaper files were more conservative and specific in reshaping the simulated root canals than other systems.

The three systems used were respecting the internal anatomy of simulated root canals other than non-conservative shaping of the straight canals, even they were within acceptable limits.

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## CONFILCTS OF INTEREST

The autor declared no conflicts of interest.

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