# The philosophies of dowel diameter preparation: A literature review

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**This article reviewed the literature regarding the diameter of dowels and identified three distinct philosophies of dowel space preparation. One group advocated the narrowest diameter for fabrication of a dowel to a desired length. Another recommended a dowel space with an apical diameter equal to one third of the narrowest dimension of the root at the terminus of the dowel. A third group advised that at least 1 mm of sound dentin should surround the entire surface of the dowel. A combination of the one third and 1 mm minimal philosophies yielded a practical guideline for dowel space preparation, particularly in aged teeth. Requiring a definite amount of tooth structure surrounding the dowel, while adhering to the one third proportion, indicated upper limits on both the diameter and length of the dowel. These calculated limits served as convenient starting points in selecting a specific style of dowel and assisted in determining whether additional measures are warranted to enhance dowel retention. (J Prosthet Dent 1993;69:32-6.)**

In restoring an endodontically treated tooth, a critical step is dowel placement, because mismanagement can result in a vertical or horizontal fracture of the root. These fractures are difficult to diagnose and commonly require extensive or radical treatment.[1] For a multirooted tooth it implies amputation of the fractured root when feasible, or may necessitate extraction of the single-rooted tooth.[2, 3] The most widely documented causes of vertical root fractures in endodontically treated teeth are related to excessive removal of tooth structure during root canal treatment or dowel placement.[4]

The resistance of an endodontically treated tooth to fracture depends on prudent management of the residual root and the design of the dowel space preparation. The dimensions of length and diameter are fundamental to the design. The apical extension of a dowel can be conveniently resolved by advocating the maximal permissible length without compromising the 3 to 5 mm apical seal of gutta-percha.[5] This dimension of the dowel is not generally identified when causes of fractured endodontically treated teeth are listed. It is the diameter of the dowel that is commonly associated with fracture. Definitive standards for dowel diameter have been proposed but, unlike dowel lengths, are repeatedly debated without resolution.

## LITERATURE REVIEW

Harris,[6] in his 1871 text on "The Principles and Practice of Dentistry," described the preparation of a natural root for an artificial crown. He recommended removing the remaining portion of the anatomic crown with an excising forceps and the extirpation of the nerve by rapid rotation of a silver wire introduced in the canal. This provided access to the canal space for a pivot (dowel) that would serve as an anchor for an artificial crown. Harris[6] contended, without explanation or supportive evidence, that the diameter of the pivot (dowel) "should never exceed the sixteenth part of an inch or a line." This narrow diameter was possibly advocated for substantial root bulk to prevent splitting, because during that period dowels consisted of well-seasoned young hickory, which gained retention by absorbing moisture and then swelling.

Although wood is now contraindicated as a dowel, the preservation of sufficient root structure to resist fracture remains valid. Dowel diameter and the remaining dentin were recently identified by Obermayr et al.[7] as variables that influenced resistance to vertical root fracture. Sorensen and Engleman[8] reviewed the effect of dowel adaptation on fracture resistance of endodontically treated teeth and specifically recommended that research should be conducted to evaluate the width of tooth structure surrounding the apical surface of the dowel. The clinical significance of residual root thickness at the apex of the dowel was emphasized by Vire,[9] who evaluated the failures of endodontically treated teeth. The fractured teeth were traced to restorative failures with consistent angular fractures emanating from the apical surface of the dowel.

Although the literature contains numerous reports on dowel length and the effect on stress distribution,[10-20] there is sparse information about dowel diameter and stress concentrations.[21] Authors have been concerned with either techniques or principles of dowel fabrication without recommending dowel diameters,[17, 22-25] or they merely suggested vague, nonspecific guidelines regarding dowel di-

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ameters. Pearl and Muroff[15] based their recommendations for dowel diameter on the sufficient "bulk" of the post to "resist bending." A canal was satisfactorily prepared, according to Shadman and Azarmehr,[26] when it ensured the fabrication of a rigid and unyielding dowel. Halle et al.[27] advised only minimal flaring for preparing dowel space for immature teeth. Baraban[14] reviewed the principles of restoring pulpless teeth and recommended gradual enlargement of the canal space for a dowel to a "suitable" size for the individual tooth.

Greenwald[28] described the fabrication of a cast-gold post and core and detailed the desired length of the dowel but only suggested caution regarding the appropriate diameter. A detailed review of the guidelines for restoring endodontically treated teeth, by Robbins,[29] was initiated with a discussion of the importance of dowel diameter. He recommended that the diameter be "as small as possible" to increase fracture resistance by minimizing loss of tooth structure. Kwiatkowski and Geller[30] used two preparation designs for glass-ceramic dowels to preserve root surface hue in endodontically treated teeth characterized as "one with no loss and one with moderate loss of tooth structure." DeSort[31] omitted entirely the discussion of dowel diameter in a summary of the theory and biomechanics of post preparation.

In 1959 Frank[32] discussed the principles of protecting the pulpless tooth and offered direction in the fabrication of dowels. He also remarked, regarding dowel preparation, that every effort should be exercised to ensure optimal retention. He advocated extending the dowel as long as practical or expanding the diameter of the dowel to improve lateral contact. He based these recommendations on a direct correlation between the lateral surface area of the dowel and retention, while also cautioning to avoid radical enlargement of the dowel space. He specifically commented that overpreparing the root for dowel placement often created a "thin shell" of dentin, implying tooth structure incapable of resisting fracture.

Potashnick et al.[33] did not recommend treatment that increased dowel diameter supposedly to improve retention or reinforce the root. They recommended reducing the dowel diameter to elevate the fracture resistance of endodontically treated teeth and contended that the increased retention by expanding dowel surface area was not as effective as extending the length of the dowel.

Vertical root fracture has been verified as the primary reason for removal of successfully treated endodontic teeth. The fracture has been attributed to both overzealous preparation of the canal space and forceful insertion of a dowel.[4] These observations are responsible for the concern expressed by many researchers regarding the overenlargement of the dowel space. Tjan and Whang[34] commented that extensive enlargement of the canal for a larger diameter dowel can weaken the tooth because of loss of dentin, resulting in root fracture during functional load. Other investigators reported that excessive dowel width only weakened the root and compromised the restoration.[35] Eissman and Radke[36] believed that abusive, overinstrumentation of the canal unnecessarily weakened the apical surface of the root. Others cautioned against expanding the canal space because of the potential for root perforation[10] and violation of the periodontal ligament.[21]

Sorensen and Martinoff[10] reported the clinically significant factors of dowel design and commented that a large dowel with strength that greatly exceeded the endodontically treated root adversely affected the prognosis. Their position was based on an examination of 1273 endodontically treated teeth that correlated reinforcement method, dowel length, and manner of failure.

Mattison[21] concluded, in a photoelastic stress analysis of cast-gold endodontic posts, that an increase in post diameter elevated stress in the radicular surfaces of the tooth. On the basis of photoelastic stress patterns in his model, he recommended conservation of tooth structure to prevent fracture in designing a dowel and core.

## PHILOSOPHIES OF DOWEL SPACE PREPARATION

Recommendations regarding dowel diameter originate from two sources: clinical experience and comparative investigations. There are presently three distinct philosophies concerning the preparation of dowel space diameter for endodontically treated teeth (Fig. 1). One group, "the conservationists," advocates the narrowest diameter that allows the fabrication of a dowel to the desired length. A second group, "the proportionists," recommends a dowel space with an apical diameter equal to one third the narrowest dimension of the root diameter at the terminus of the dowel space. The third group, "the preservationists," advises that at least 1 mm of sound dentin should surround the entire surface of the dowel.

### The Conservationist

An extremely conservative approach to dowel space preparation has been proposed by several investigators.[21, 33, 37-39] This group generally advocates only minimal instrumentation of the canal after removal of gutta-percha. The instrumentation is limited to removal of undercuts that prevent withdrawal of dowel patterns, because endodontically treated teeth with the smaller diameter dowels resist fractures better.[40] Robbins[29] specifically recommended the most conservative dowel that provided adequate retention without compromising the fracture resistance of the root. Potashnick et al.[33] also reported that teeth with smaller dowels demonstrated greater resistance to fracture and recommended only minimal flaring of the canal. Fehling and Wolfert[37] examined the rationale and techniques for fabricating custom cast dowels for anterior teeth and advised enlarging the canal until clean dentinal shavings extruded from the orifice. Goering and Mueninghoff[38] recommended that dowel preparation should only minimally alter the internal anatomy of the canal. They further commented that if the canal had been satisfactorily flared, minimal alteration was required to fabricate a

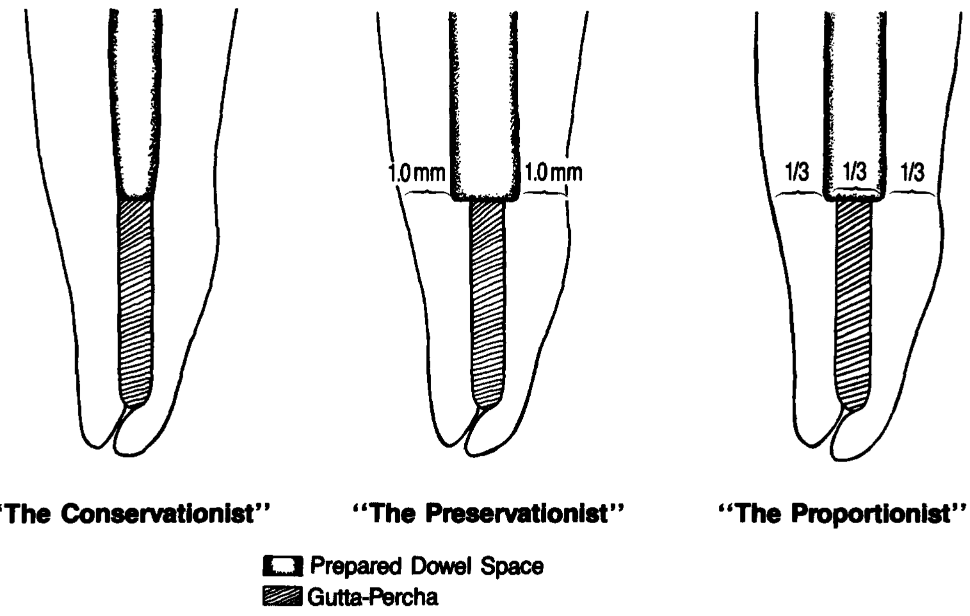


**Fig. 1.** The philosophies of dowel diameter preparation (labial view of left mandibular canine).

**Table I.** Proponents of different philosophies of dowel diameter preparation

| The Conservationists | The Proportionists | The Preservationists |
|---|---|---|
| Assif et al.[41] | Eissmann and Radke[36] | Barkhordar et al.[52] |
| Bergman et al.[43] | Gerstein and Evanson[53] | Caputo and Standlee[51] |
| Brandal et al.[45] | Hunter et al.[50] | Colman[55] |
| Fehling and Wolfert[37] | Johnson et al.[48] | Halle et al.[27] |
| Goering and Mueninghoff[38] | Shillingburg and Kessler[5] | Marshak et al.[54] |
| Gutman[39] | Stern and Hirshtelo[16] | Trabert and Cooney[36] |
| Haddix et al.[42] | Tilk et al.[49] | |
| Larato[24] | | |
| Mattison[21] | | |
| Potshnick et al.[33] | | |
| Sheets[46] | | |
| Snyder[47] | | |
| Zarb et al.[44] | | |

dowel. Mattison[21] also suggested restricting the diameter of the dowel to conserve remaining tooth structure. Assif et al.[41] suggested using the narrowest of cylindrical drills that would reach the desired depth for dowel space preparation for simultaneous dowel cementation and core fabrication. While examining the effect of three different techniques for dowel space preparation on the apical seal, Haddix et al.[42] considered the flaring from the initial canal instrumentation sufficient for dowel construction. Gutman[39] advocated only slight enlargement of the existing canal anatomy for dowel space, referred to as "internal shaping of the canal."

Many articles describing the fabrication of dowels contain schematic diagrams of the procedures. These schematics often reveal undeclared philosophies on dowel diameter. Evidence to support conservative philosophy for dowel space preparation can be observed in the schematic diagrams of several authors.[24, 43-47] The most revealing diagrams are the contrasting pictorials of Gutmann[39] that depict the extremes of dowel preparation such as slightly modified and overprepared canal spaces.

## The Proportionist

The development of a dowel space in proportion to the root structure is a concept perpetuated by many investigators and dentists. Stern and Hirshtelo[16] and Johnson et al.[48] recommended that the optimal diameter of the dowel was one third the diameter of the root. Trabert and Cooney[35] advocated the preparation of a dowel space that did not exceed one third the width of the root at its narrowest dimension. This clinical guideline for determining the appropriate diameter of dowel, according to Shillingburg and Kessler,[5] generally involved the mesiodistal width of roots.

Tilk et al.[49] applied the "one third principle" in an exhaustive study of mandibular and maxillary root widths, and recommended ranges for dowel diameters for each tooth. They suggested that the one third relationship preserved sufficient tooth structure to resist root fracture. These established dimensions for posts have been used by other investigators studying different dowel characteristics.[50]

### The Preservationist

The philosophy of dowel space preparations depends on a minimal thickness of dentin surrounding the entire dowel to prevent tooth fracture. Caputo and Standlee[51] proposed that at least 1 mm of sound dentin be maintained around the entire circumference. Halle et al.[27] compared in vitro prefabricated and custom dowels and cores and concluded that the ideal was 1.75 mm of tooth structure remaining in any direction from the margin of the prepared dowel. In an investigation examining the effect of metal collars on resistance to fracture, dowel space was prepared so that 1 mm of dentin remained along the entire facial wall.[52] Trabert and Cooney[35] further qualified their "one third" rule by recommending that the dowel be surrounded by a minimum of 1 mm of sound root structure.

## CLINICAL APPLICATION

The search for an ideal restoration of an endodontically treated tooth has been elusive. Variations in anatomic configuration, extent of destruction, location in the dental arch, supporting alveolar bone, and the designated function of the restored tooth in replacing or supporting other teeth complicate the selection of the most appropriate dowel for a specific clinical situation. Three distinct philosophies of dowel diameter preparation and the proponents of each were identified to clarify the direction of treatment (Table I).

Treatment philosophies for preparing dowel space may not have high clinical relevance in teeth with wide canals, such as young adult dentition. However, in the aged with a lifetime of secondary dentinal deposition, canal enlargement is crucial for achieving appropriate dowel dimensions without compromising the remaining tooth structure.

A convenient starting point for dowel selection is 5 mm from the anatomic apex. By calculating the narrowest width of the root at this site and applying the philosophies of the proportionist and preservationist, an optimal diameter and length can be determined. This provides a dowel with suitable rigidity to resist deformation while evenly distributing forces to the residual tooth. Additional features can be included in the design of the dowel such as various surface textures or geometric forms of auxiliary retention and a specific luting agent.

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# Effect of post design on resistance to fracture of endodontically treated teeth with complete crowns

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**The effect of post design on the fracture resistance of endodontically treated premolars restored with cast crowns was examined in vitro. The experimental model used cast posts and cores to test the effect of post design in a post-core system with identical rigidity. Samples loaded on an Instron testing machine until failure revealed that post design did not influence the fracture resistance of endodontically treated premolars restored with complete cast crowns. There was also no statistically significant difference between restored teeth with or without cast posts and cores. (J PROSTHET DENT 1993;69:36-40.)**

A post-core system is usually inserted to restore damaged teeth after endodontic treatment.[1,2] The functions of a dowel placed in the root canal of the restored tooth are (1) to disperse occlusal forces along the root; and (2) to provide retention of the core substituting for coronal tooth structure and supporting or retaining the final restoration.[1-5]

Techniques available for constructing a dowel and core are (1) the conventional dowel and core cast as a single unit with the shape of the dowel conforming to the morphology of the root canal;[1-3] (2) a dowel-core, prefabricated commercial post of various designs used with cores of various materials (such as amalgam, composite resin, or glass ionomer cement);[1,3,5,6] and (3) cast dowel and core in which the post is identical to a prefabricated commercial post. In the third technique, the commercial prefabricated plastic model of the post is used as a pattern to cast the restoration.[1,4]

Controversy exists concerning dowel design for endodontically treated teeth. Some investigators claim that a cylindrical post disperses the occlusal forces evenly along the root,[1,7] whereas others contend that a cylindrical dowel causes stress concentration in the apical surface of the root.[8,9] Several researchers also demonstrated that tapered or tapered-end dowels caused a wedging effect,[7,10] but

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