"Ex vivo" determination of the clinical anatomic diameter in human maxillary and mandibular molar teeth at different levels

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ABSTRACT

Objective: This study aimed to measure the clinical anatomical diameter of root canals in human molars at different levels. **Methods:** Fifty maxillary and fifty mandibular molars were axially cross-sectioned and analyzed at 1 mm, 5 mm and 9 mm from the anatomical apex. The fourth level was in the root canal opening. The first file adjusted at root canal walls without pushing was recorded. Mean values and standard deviations were calculated using paired t-test. **Results:** Diameter at root canal entrance (RCE) and cervical level in disto-buccal canals of maxillary molars and mesio-buccal as well as mesio-lingual canals of mandibular molars were 30.71 ± 9.74 and 37.10 ± 9.17, 41.80 ± 10.71 and 46.80 ± 10.62, 37.40 ± 10.25, and 44.50 ± 10.64 (mm x 10^{-2}), respectively. At the apical third, maxillary molars showed mean diameters of 22.00 ± 4.79, 21.80 ± 5.81, and 39.40 ± 10.18 for mesio-buccal, disto-buccal and palatal canals, respectively. For mandibular molars, mean value was 26.90 ± 9.79, 24.00 ± 6.85, and 36.44 ± 10.18 for mesio-buccal, mesio-lingual and distal canals, respectively. **Conclusions:** RCE of disto-buccal canals of maxillary molars and mesial canals of mandibular molars presented smaller diameter than the cervical third. Mesial canals of mandibular molars and buccal canals of maxillary molars had diameter close to #25 and #20 K-files at 1 mm apical level, respectively. Palatal canals of maxillary molars and distal canals of mandibular molars presented diameter close to #40 and #35 K-files at 1 mm apical level, respectively.

Keywords: Endodontics. Dental pulp cavity. Root canal preparation.

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Introduction

The aims of root canal instrumentation are cleaning and shaping to promote debridement and disinfection of the root canal system as much as possible. They also comprise creating a suitable shape for complete three-dimensional filling.[1] Some iatrogenic procedural errors, such as zipping, canal transportation, ledging and root perforations could occur during root canal preparation, especially when low flexibility stainless steel (SS) instruments are associated with conventional serial techniques. Due to these problems, root canal enlargement has been carried out with small gauge instruments. Minimal apical enlargement can avoid apical lacerations and ledging, but are not sufficient to completely clean and disinfect the root canal system, and maintenance of microorganisms may compromise endodontic treatment.[2,3,4]

There are various philosophies with regard to the ideal size of apical enlargement. Some authors proposed enlarging the apical third of the root canal three or four ISO-sizes more than the first file that binds root canal walls at working length.[5,6] Kerekes and& Tronstad[7] are guided by the knowledge of root canal anatomy, while Cohen[8] and Ingle[9] recommend keeping the apex as small as possible. Furthermore, recommendations for curved canals indicate that apical instrumentation should not go beyond #25 or #30.[6]

Despite those differences, the starting point for apical enlargement is to find the first file that fits the apex.[10-15] But there is much interference between the cervical and middle thirds of root canal walls,[16] and frequently the first file to bind does not reflect the apical canal diameter.[15] Existing root canal entrance obstruction are commonly a consequence of reaction dentin deposition.[17] Tactile determination of the apical diameter is a difficult procedure, but precision can increase by adopting some clinical procedures, such as preflaring, regardless of the instrument used for this purpose.[10,15]

In 1988, Walia et al[18] introduced the nickel-titanium (NiTi) alloy to manufacture endodontic instruments; and since 1996, engine-driven NiTi instruments have been available for root canal preparation. The taper of these instruments creates an adequate conical continuous shape to facilitate obturation. On the other hand, rotary NiTi instrumentation are frequently used reduting apical enlargement and increase taper of preparation.[19] As a result, satisfactory flaring is achieved and more dentin and interference are removed not only from the root canal opening, but also from the cervical third, thus improving the conditions for penetration of irrigants into the apical third of canals and eliminate bacteria as well as debris during cleaning and shaping.

Therefore, what is more important in root canal cleaning and shaping? Increase in preparation taper or apical third enlargement? Specifically about molar root canals, Kerekes and Tronstad[7] showed that 95% of mesial root canals required at least #60 instrument for ful apical preparation at 1 mm. Shupping et al[20] found better antibacterial effect during NiTi instrumentation when NaOCl was used, but only after instrumentation exceeded ISO size #30 to #35. According to Khademi et al,[21] the minimum instrumentation size for irrigant penetration into the apical third of the root canal is a #30 file. However, Wu and Wesselink[22] showed better cleaning after instrumentation reached #45 apical file.

Albrecht et al[23] and Usman et al[24] showed that debris were more effectively removed when preparation size was larger than #40 compared with #20 apical preparations, despite the use of 0.04, 0.06 and 0.08 taper instruments. Rollison et al[25] found better results for debridement in infected root canals when the apical third was instrumented to an apical width of #50/.02 than apical preparation with instruments not greater than #35/.04. The probability is that both taper and diameter are equally important in chemomechanical instrumentation of the root canal system.

Due to difficulty establishing a suitable instrument diameter for apical preparation, the aim of the present study was to determine ex-vivo the clinical anatomical diameter of maxillary and mandibular molars root canals at different levels in order to improve knowledge for adequately enlargement of the root canal system.

Methods

One hundred extracted human first and second molars (fifty maxillary and fifty mandibular ones), obtained from a teeth bank, were used. This study was approved by local Research Ethics Committee. Teeth without calculus and residual bone tissue adhered

to the roots were preserved in 0.1% thymol solution (Pharmacy Salvena, Curitiba, PR, Brazil). Samples with incomplete apex formation, merged roots, presence of canal calcification and/or previous endodontic treatment were excluded from this study. All teeth showed length between 12.0 and 13.0 mm from the enamel-cementum junction.

The roots were axially cross-sectioned at four different levels using Isomet low-speed sectioning machine (Buehler Ltd, Evanston, IL, USA) with a diamond bur (15HC, Buehler Ltd, Evanston, IL, USA). Vertical grooves at the buccal surface of teeth were made to allow identification of the root side. The first (apical), second (middle) and third (cervical) levels were made at 1 mm, 5 mm and 9 mm from the anatomical apex, respectively. The fourth level section was made at the middle part of the crown. Care was taken to preserve the floor of the pulp chamber and root canal opening (RCE) without damage. The identified root-sectioned fragments were placed into the ultrasonic cleaner (BioWash STD, Shenzhen Codyson Electrical Co, China) with 2.5% sodium hypochlorite (Pharmacy Salvena, Curitiba, PR, Brazil) and activated for 10 minutes to have pulp tissue and dentin debris removed.

The 1-mm, 5-mm and 9-mm levels measures were taken at the same sectioned surface, but the fourth level was taken in RCE (Fig 1). Subsequently, for measurements, ISO K-file SS hand instruments (Dentsply/Maillefer, Ballaigues, Switzerland) were gently introduced in ascending order, beginning with #10 and followed, if necessary, up to #140. Instruments were inserted only into the first millimeter of the sectioned root canal until binding. If the tip did not bind, the new larger K-file in ISO sequence was selected and the process was repeated. The instrument adapted to root canal walls was recorded as having compatible diameter in each level of the mesio-buccal (MB), disto-buccal (DB) and palatal (P) canals of maxillary molars, and mesio-buccal, mesio-lingual (ML) and distal (D) canals of mandibular molars. If the distal root showed two canals, measures were taken in the disto-buccal and disto-lingual (DL) canals. Mesio-buccal2 (MB2) canals of maxillary molars were not evaluated.

All measurements were carried out under 40X magnification using an operative microscopic (DFVasconcelos, Valença, Rio de Janeiro, Brazil). The adapted file size data were statically evaluated by paired t-test.

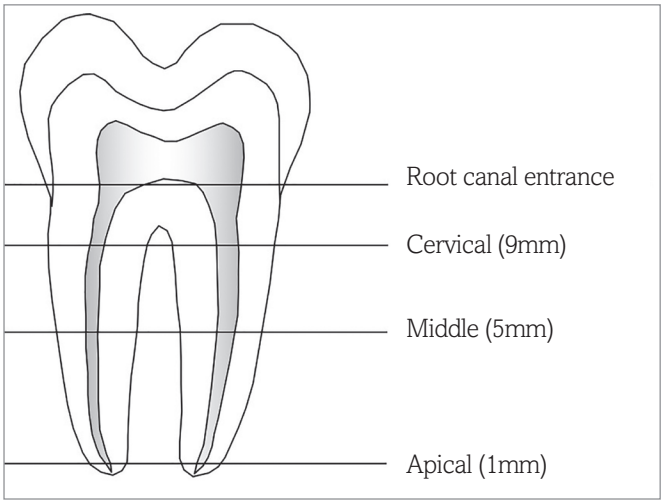

Figure 1. Schematic drawing showing root canals measurement levels of mandibular molars. The same levels were used for maxillary molars .

Results

The frequency of instrument size that binds at RCE, cervical (9 mm), middle (5 mm) and apical (1 mm) levels of maxillary and mandibular molars root canals are summarized in Tables 1 and 2, respectively. Tables 3 and 4 show mean clinical anatomical diameter and standard deviation (SD) at RCE, cervical, middle and apical levels of maxillary and mandibular molars root canals expressed in mm x 10^{-2}. ISO files #130 and #140 were not used at any level of the teeth.

Maxillary molars

Root canal anatomical diameters of maxillary molars do not follow a consistent pattern. There was a high variability of diameters from RCE to the apical sections. The mean value at RCE of the MB canal was 40.20 ± 9.16, with values following in descending order. In the cervical, middle and apical thirds mean values were 37.90 ± 7.55, 36.40 ± 6.85, and 22.00 ± 4.79, respectively. In DB canals, RCE showed a mean value (30.71 ± 9.74) lower than the cervical section (37.10 ± 9.17). After this level, followed with similarities to MB canals, and the mean values were 34.20 ± 9.40 and 21.80 ± 5.81 for middle and apical sections, respectively.

As regards palatal canals, a decreasing mean value was found, starting in RCE with 78.90 ± 19.42, followed by , cervical 74.50 ± 15.37, middle 58.60 ± 12.85 and apical thirds 39.40 ± 10.18, respectively (Table 3).

Mandibular molars

Regarding mandibular teeth, MB canals were larger than ML canals at all levels, and the largest diameter was found in the cervical third, not in RCE . MB and ML canals showed that the mean value of clinical diameter in root canal entrance (41.80 ± 10.71 and 37.40 ± 10.25) was lower than the cervical third (46.80 ± 10.62 and 44.50 ± 10.64). After this level, values of clinical diameter decreased. At the middle third, the clinical diameter of MB and ML was 38.50 ± 10.64 and 35.50 ± 10.21, whereas in the apical third, it was 26.90 ± 9.79 and 24.00 ± 6.85, respectively.

In the distal root, 38 samples (76%) showed one canal, while 12 samples (24%) had two canals. With one distal canal, the mean values found were 67.11 ± 21.75 in RCE, followed by 64.73 ± 13.37 (cervical), 55.39 ± 14.66 (middle) and 36.44 ± 10.18 (apical). But when two distal root canals were found, the mean values for DB canals were 44.16 ± 12.80 for RCE, and 43.33 ± 7.16, 41.25 ± 7.10, and 32.08 ±10.49 for the cervical, middle and apical thirds, respectively. For DL canals, the mean value was 40.00 ± 12.58 for RCE, and 40.00 ± 8.90, 35.83 ± 6.71, and 26.25 ± 7.39 for the cervical, middle and apical thirds, respectively (Table 4).

Table 1. Relationship between file size of instrument and frequency at root canal entrance, cervical, middle and apical thirds of the maxillary molar root canals.

Size of instrumen	MAXILLARY MOLAR											
	Root canal enlargement			Cervical (9mm)			Middle (5 mm)			Apical (1mm)		
	MV	DV	P	MV	DV	P	MV	DV	P	MV	DV	P
# 10	-	-	-	-	-	-	-	-	-	-	-	-
# 15	-	1	-	-	-	-	-	-	-	6	12	-
# 20	1	9	-	1	1	-	-	3	-	26	18	4
# 25	2	12	-	3	6	-	7	10	-	13	13	4
# 30	7	12	-	6	9	-	6	9	-	2	6	1
# 35	10	6	-	15	16	1	14	14	4	3	-	12
# 40	13	1	2	14	3	-	15	7	4	-	-	10
# 45	6	6	1	6	8	1	6	3	2	-	1	10
# 50	6	1	-	2	3	2	1	2	5	-	-	4
# 55	2	2	4	3	3	3	1	1	8	-	-	2
# 60	3	-	4	-	1	5	-	-	8	-	-	3
# 70	-	-	10	-	-	14	-	1	15	-	-	-
# 80	-	-	14	-	-	11	-	-	4	-	-	-
# 90	-	-	5	-	-	9	-	-	-	-	-	-
# 100	-	-	3	-	-	3	-	-	-		-	-
# 110	-	-	5	-	-	1	-	-	-	-	-	-
# 120	-	-	2	-	-	-	-	-	-	-	-	-
# 130	-	-	-	-	-	-	-	-	-	-	-	-
# 140	-	-	-	-	-	-	-	-	-	-	-	-
Total	50	50	50	50	50	50	50	50	50	50	50	50

MB = Mesio-buccal root canal; DB = Disto-buccal root canal; P = Palatal root canal

Table 2. Relationship between file size of instrument and frequency at root canal entrance, cervical, middle and apical thirds of mandibular molar root canals.

Size of instrument	MANDIBULAR MOLAR																			
	Root canal entrance					Cervical (9 mm)					Middle (5 mm)					Apical (1 mm)				
	MB	ML	D	DB	DL	MB	ML	D	DB	DL	MB	ML	D	DB	DL	MB	ML	D	DB	DL
# 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# 15	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	6	9	-	-	1
# 20	3	2	-	-	-	1	-	-	-	-	2	3	-	-	-	12	17	2	2	2
# 25	5	6	-	-	2	-	-	-	-	-	3	10	-	-	-	12	7	4	4	6
# 30	2	9	3	3	3	1	7	-	-	2	10	8	3	1	6	10	10	9	1	1
# 35	6	3	1	3	2	7	7	-	1	4	11	13	2	2	1	5	6	10	2	1
# 40	6	14	-	-	-	7	7	2	8	3	10	3	3	4	3	3	1	4	-	-
# 45	9	10	3	1	1	12	13	2	-	1	7	5	3	3	1	-	-	3	1	1
# 50	13	3	4	-	-	10	7	3	1	-	2	5	5	1	1	1	-	3	2	-
# 55	4	-	-	4	3	7	3	4	1	1	2	1	6	-	-	-	-	-	-	-
# 60	2	1	6	-	1	3	4	10	1	1	1	2	6	1	-	-	-	3	-	-
# 70	-	1	10	1	-	-	1	6	-	-	2		5	-	-	1	-	-	-	-
# 80		-	4	-	-	2	1	9	-	-	-	-	5	-	-	-	-	-	-	-
# 90	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
# 100	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# 110	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# 120	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# 130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# 140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	50	50	38	12	12	50	50	38	12	12	50	50	38	12	12	50	50	38	12	12

MB= Mesio-buccal root canal; ML= Mesio-lingual root canal; D= Distal root canal; DB= Disto-buccal root canal; DL= Disto-lingual root canal.

Table 3. Mean (in millimeters x 10-2) and standard deviation at root canal entrance, cervical, middle and apical thirds of maxillary molar root canals.

Levels	MAXILLARY MOLARS		
	MB	DB	P
	Mean ± SD	Mean ± SD	Mean ± SD
Root canal entrance	40.20 ± 9.16	30.71 ± 9.74	78.90 ± 19.42
Cervical (9 mm)	37.90 ± 7.55	37.10 ± 9.17	74.50 ± 15.37
Middle (5 mm)	36.40 ± 6.85	34.20 ± 9.40	58.60 ± 12.85
Apical (1 mm)	22.00 ± 4.79	21.80 ± 5.81	39.40 ± 10.18

MB = Mesio-buccal root canal; DB = Disto-buccal root canal; P = Palatal root canal; SD = Standard deviation

Table 4. Mean (in millimeters x 10-2) and standard deviation at root canal entrance, cervical, middle and apical thirds of mandibular molar root canals.

Levels	MANDIBULAR MOLARS				
	MB	ML	D	* DB	* DL
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Root canal entrance	41.80 ± 10.71	37.40 ± 10.25	67.11 ± 21.75	44.16 ± 12.80	40.00 ± 12.58
Cervical (9 mm)	46.80 ± 10.62	44.50 ± 10.64	64.73 ± 13.37	43.33 ± 7.16	40.00 ± 8.90
Middle (5 mm)	38.50 ± 10.64	35.50 ± 10.21	55.39 ± 14.66	41.25 ± 7.10	35.83 ± 6.71
Apical (1 mm)	26.90 ± 9.79	24.00 ± 6.85	36.44 ± 10.18	32.08 ± 10.49	26.25 ± 7.39

MB = Mesio-buccal root canal; ML = Mesio-lingual root canal; D = Distal root canal; DB = Disto-buccal root canal; DL = Disto-lingual root canal; SD = standard deviation; * DB and *DL when distal root showed two canals.

Discussion

The anatomical condition is a fundamental factor that should be considered before root canal instrumentation. Furthermore, the anatomical diameter is an important parameter to guide the limits of root canal enlargement. Different methodologies can be used to evaluate root canal anatomy, as microcomputed tomography (μCT) which provides high resolution three-dimensional images and several quantitative data.[26,27] However, the root cross-section technique is a valuable method for clinical evaluation of anatomical diameter of teeth, as performed in this study.

Previous studies propose the insertion of endodontic files from RCE in non-sectioned teeth;[10-15] however, false conclusions may be drawn. Most studies try to make a correlation between instrument size and anatomical diameters of root canals. Nevertheless, they have some limitations because when the instrument is fitted into the canal, it fits at only two points of the dentinal wall and does not reflect the anatomical diameter, but only instrument adaptation. The probability is that it reflects the minor diameter because apical anatomy is often irregularly shaped and not of round configuration.[22,28]

This shows that true anatomy of the root canal system is difficult to be determined by clinical methods.[27] Despite the referred limitations, determining root canal diameter with hand files is the most viable method for application in clinical routine, since file diameter can be used as an acceptable correlation to determine root canal diameter.[11-13] Therefore, in the present study, the anatomical diameters of human maxillary and mandibular molars were evaluated with passive insertion of different files at four different levels.

Our results showed differences between the clinical anatomical diameter of maxillary and mandibular molars in all canals at different levels. An important finding was that RCE diameter of maxillary MB molar and mandibular MB and ML molar showed lower diameters than the cervical level (Tables 3 and 4). This is of great clinical relevance, because when the file is inserted into the canal, the sensation of instrument fitting is not a result of tip fitting, but due to contact with dentin of the RCE. These results corroborate the findings by Phillipas[17] which showed that age and oclusal forces may change the pulp anatomy, and RCE became more centralized into the floor of the pulp chamber due to dentin deposition. Moreover, Leeb[16] was ground-breaking in showing that when the instrument is inserted into the canal, the tug-back sensation occurs in any area of the RCE or at the cervical level, not in the apical third. Due to the aforementioned factors, coronal flaring and crown-down shaping of root canals have been recommended since the 80s. Several studies showed an increase in accuracy when determining the anatomical diameter of the apical third when preflaring of the coronal and middle thirds was carried out.[11,12,17]

In the middle third (5-mm level) of all teeth for all root canals, mean anatomical diameter had few variations. Showing that, after RCE, i.e. between cervical and middle levels of root canals, mean anatomical diameter decreases (Tables 3 and 4).

Our results showed the anatomical diameter of MB and DB canals of maxillary molars 1.0 mm shorter than the anatomical apex ranged from 21.80 ± 5.81 to 22.0 ± 4.79, while for mandibular molars it ranged from 26.90 ± 9.79 to 24.0 ± 6.85 for MB and ML canals, respectively (Tables 3 and 4). Villas-Bôas et al,[27] using μCT analysis, found similar results in mesial root canals of mandibular molars at the same level. Contemporary clinical procedures, such as preflaring and crow-down shaping, could enhance root canal anatomical diameter determination. According to Silveira et al,[17] the referred techniques had an estimate of apical diameter larger than #25 file in mandibular root canals.

Apical enlargement with smaller file diameter, such as #20 and #25, is a good method to avoid apical deformation and instrument breakage, but it is below minimal apical enlargement necessary to achieve cleaning and disinfection.[29] The classical rule used to enlarge the root canal with three or four files larger than the first instrument that bind in root canal walls at the working length was suggested by Weine;[6] however, it should be considered that preflaring and crown-down techniques were unusual at that time. Thus, with the use of these techniques two instruments that are larger than the anatomical file that bind at the working length can be enough for cleaning and shaping the apical third.[15] According to our results and the recommendation by Silveira et al,[15] we

can estimate that master apical file (MAF) for mesial canals of mandibular molars and buccal canals of maxillary molars the #35.

In rotary instrumentation technique, the recommendation of minimal apical enlargement is generally associated with the use of NiTi instruments with greater taper.[19] At present, there are two different ways to determine the final shape of root canal preparation end: the classical apical stop and the apical seat. In the apical stop, a well-defined box shape is created using larger files than the initial file that bind at 1.0 mm short the anatomical apex. The apical seat shape is formed using instruments with continuous taper up to the end of the root canal with enlargement of apical constriction, i.e, enlarging the opening of the minor foramen.[19] It does not matter what is the shape used to define apical end. The most important thing is that the final diameter of root canal enlargement, 1.0mm short the anatomical foramen, is enough to enlarge the apical third, remove pre-dentin and make obturation easier.

Our results suggest that when apical enlargement is equivalent to #25 file for mesial canals of mandibular molars and buccal canals of maxillary molars, most likely little cleaning was achieved because #25 file measures are close to the clinical anatomical diameter, and root canals need to be enalrged more than this diameter to promote disinfection. According to Shuping et al,[20] the apical third must be enlarged up to #35 file to promote adequate disinfection and Khademi et al[21] showed that apical enlargement necessary for penetration of irrigants was at least a #30 file.

But if apical root canal enlargement is carried out with instruments three or four ISO-sizes more than the first file that binds root canal walls at working length,[5,6] mesial root canals of mandibular molars will be enlarged up to the #40 or #45 files. Hoskinson et al,[30] in a retrospective study, reported that the diameter of the last file used had no influence over endodontic treatment, particularly when #20 and #40 files were used, but there was an increase in apical lesion healing when apical enlargement was performed with larger files in cases of apical periodontitis.

In the distal canal of mandibular molars (with one root canal only) and palatal canals of maxillary molars, mean anatomical diameter at the apical level was 36.44 ±10.18 and 39.40 ±10.18, respectively (Table 3 and 4). To increase this diameter during instrumentation, with further disinfection, files tip #45 and #50 are necessary.

If larger files are necessary to increase apical enlargement in the presence of curvatures, the question is: How should they be used without causing any damage, such as zip, canal transportation, ledging and root perforations? Stainless steel instruments do not have appropriate flexibility; therefore, NiTi manual or engine-driven files with lower taper are recommended.

There will always be doubts about the ideal enlargement for root canal cleaning and disinfection, especially when curvatures are present, but knowledge of the anatomical diameter can be a satisfactory way to achieve this goal.

Conclusions

1. RCE of disto-buccal canals of maxillary molars and mesial canals of mandibular molars showed smaller diameter than the cervical third.

2. Mesial canals of mandibular molars and buccal canals of maxillary molars showed clinical anatomical diameter close to #25 K-file and #20 K-file at 1-mm apical level, respectively.

3. Palatal canals of maxillary molars and distal canals of mandibular molars showed clinical anatomical diameter close to #40 K-file and #35 K-file at 1-mm apical level, respectively.

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