Anatomical Variations of the Bifid Mandibular Canal on Panoramic Radiographs in Citizens from Zagreb, Croatia

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Abstract
The bifid mandibular canal (BMC) is an anatomical variation with reported prevalence ranging from 0.08 to 65%. Identifying anatomical variations of mandibular canal is very important in order to prevent possible complications during oral surgical and other dental procedures. Objectives: The aim of this study was to determine the prevalence and to classify the morphology of BMCs using digital panoramic radiographs. Material and methods: A retrospective study was conducted that included 1008 digital panoramic radiographs (412 female and 596 male) used to identify the type of BMC. Panoramic radiographs were analyzed by three oral surgeons and one dentist, and BMCs were classified into six different types, 4 types according to Langlais et al. (types 1-4), and two new types (types 5 and 6) described by authors. Results: The prevalence of BMC was 4.66% (n=47), with no significant differences in gender between BMC types (P=0.947; χ²=0.74). The prevalence of type 1 BMC was 0.79% (n=8), type 2 2.08% (n=21), type 3 0.30% (n=3), type 4 0.0% (n=0), type 5 0.89% (n=9) and type 6 0.60% (n=6). Conclusion: This study revealed a relatively high prevalence of BMCs among Zagreb citizens. Furthermore, two new types of BMCs were described. These results stress the importance of a careful and thorough radiographic analysis prior to each invasive procedure in the mandible.

Uvod
Godine 1973. Patterson i Funke (1), te Kiersch i Jordan (2) prvi su upotrijebili naziv dvostruki mandibularni kanal (DMK). Do tada se najčešće ta pojava opisivala kao jedinstvena struktura s potencijalnim malim ograncima uzduž glavnoga živca. Nadalje, navodi se da pojedine grane mogu biti dovoljno velike za oblikuju DMK i trostruki mandibularni kanal (TMK) (3).

Dvostruki mandibularni kanal je anatomski varijacija koja se smještena u tijelu ili uzlaznom kraku donje čeljusti gdje se mandibularni kanal dijeli u dvije grane. Mandibularni živac podijeljen je na prednju granu koja sadržava motoričke ograne i jedan senzorički živac (bukalni) i stražnju granu sa senzoričkim ograncima. Mandibularni kanal počinje mandibularnim otvorom i proteže se do mentalnog otvora te obrađuje se ili uzlaznim krakom donje čeljusti.
Dvostruki mandibularni kanal

Miličević i sur.

Sagittal ramus split osteotomy are just some of the procedures that began to pay more attention to the potential existence when the first case was reported, clinicians and researchers started to focus on determining the course and position of the mandibular canal and identifying possible anatomical variations. After 1973, when the first case was reported, clinicians and researchers began to pay more attention to the potential existence of BMC. Third molar extraction, dental implant placement, enucleations of pathologies, peri-apical surgery and sagittal ramus split osteotomy are just some of the procedures in which determining the position of the mandibular canal is crucial, as it is involved in incisive vascular. Radiologists are aware of the mandibular canal because it is a common anatomical landmark. However, there are some additional considerations that should be taken into account when planning surgical procedures that involve the mandible. These considerations include the possibility of variations in the mandibular canal anatomy, which can affect the surgical approach and the risk of damaging blood vessels and nerves. Therefore, a thorough understanding of the mandibular canal anatomy is essential for successful surgical outcomes.

Various types of BMCs have been described and classified according to anatomical location and based on panoramic radiographs or CBCTs. There are several classifications of BMC in the literature in the past 50 years: BMC classification by Nortje et al. (1977), Langlais et al. (1985), Kieser et al. (2005), Naitoh et al. (2009), Kuribayashi et al. (2010), Rashid et al. (2011) and Andrade et al. (2015) which divide BMCs into four different types, except the classification by Rashid et al. (13) which divides them into three types. The most commonly used BMC classification in the literature is the one by Langlais et al. (10) from 1985 (3, 4, 15). In the Langlais et al. classification, type 1 (Figure 1) refers to an unilateral or bilateral bifurcation extending to the region of the third molar or surrounding area. Type 2 (Figure 2) refers to an unilateral or bilateral bifurcation extending along the main canal and then merging in the mandibular ramus or body. Type 3 (Figure 3) refers to a combination of type 1 and 2, and type 4 (Figure 4) refers to BMC originating from two distinct mandibular apertures which afterwards merge into a single, broad mandibular canal (10).

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of the utmost importance (16). Furthermore, BMCs are often associated with the failure to obtain an adequate anesthesia on IAN (17).

The aim of this study was to determine the prevalence of BMC variations following the Langlais’s et al. classification (10), by analyzing digital panoramic radiographs taken at the University Hospital Dubrava, Zagreb, Croatia.

Materials and methods

A retrospective study was carried out that included 1008 randomly selected digital panoramic radiographs taken from the University Hospital Dubrava database, in Zagreb. All radiographs were taken between January 2019 and August 2020.

Patients of both genders, older than 18 years of age were included in this study. Apart from a person’s age, the exclusion

Materijali i metode

Provedena je retrospektivna analiza 1008 nasumično odbiranih digitalnih ortopantomogramskih snimki pohranjenih u arhivskoj bazi Kliničke bolnice Dubrava. Sve odabrane radiološke snimke učinjene su između siječnja 2019. i kolovoza 2020. godine.

U istraživanje su bili uključeni punoljetni pacijenti oba spola. Isključujući kriterij, osim godina, bili su ortopan-
criteria included a low-quality panoramic radiograph. Digital panoramic radiographs were obtained using the Ortopantomograph Soredex (Nahkelantie 160, Tuusula, Finland), adjusted at 66 kVp, 8.0mA, and acquisition time of 16.4 s. All of the radiographs were projected and analyzed on a monitor screen by four experienced clinicians. The identification of BMC was confirmed if two radiolucent lines were present in the area of IAN, if at least 3 radiopaque borders were clearly visible on the panoramic radiograph and if the research team (one dentist and three oral surgeons) agreed with the finding. According to the criteria set by Langlais et al., BMCs were classified into four different types (Figure 1-4) (10). Type 4 BMC according to Langlais et al. was not registered in this study. In addition, we identified two new types that are not described in the Langlais et al. classification. We named them type 5 and type 6 (Figure 5-6) BMC. The description of BMC types is presented in Table 3.

The prevalence of BMC types is presented in Table 2. Type 2 BMC was the most common BMC type, followed by type 5 and type 1. Unilateral BMC (63.8%, N=30) was more common than the bilateral BMC (36.2%, N=17).

Results

The total prevalence of BMC was 4.66% (n=47). As expected, there were more single mandibular canals registered than BMCs (χ² =22.183, P<0.0001). No significant difference was found between male and female patients (χ² =0.736, P=0.947) although more BMCs were detected among the male population (76.60% of the total BMCs identified) (Table 1). No statistically significant differences were found between the types of BMCs (χ² =6.979, P=0.137) (Table 2). Type 2 BMC according to Langlais et al. was not registered in this study. In addition, we identified two new types that are not described in the Langlais et al. classification. We named them type 5 and type 6 (Figure 5-6) BMC. The description of BMC types is presented in Table 3.

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Table 1. Prevalence of bifid mandibular canal by gender

| Total number of x-rays • Ukupni broj ortopantomograma | Male • Muškarci | Female • Žene |
|------------------------------------------------------|-----------------|---------------|
| 1008                                                 | 596             | 412           |

Bifid mandibular canal (N, %) • Dvostruki mandibularni kanal (N, %)

| 47 (4.66) | 36 (6.04) | 11 (2.67) |

Statistics • Statistika

χ² =0.736; P=0.947

Table 2. Prevalence of different types of bifid mandibular canals

| Total • Ukupno | Female • Žene | Male • Muškarci | Unilateral • Unilaternal | Bilateral • Bilateral |
|----------------|---------------|-----------------|--------------------------|------------------------|
| 8 (17.02%)     |              | 2               | 6                        | 8                      | 0                      |
| 21 (44.68%)    | 4             | 17              | 11                       | 10                     |
| 3 (6.38%)      | 1             | 2               | 0                        | 3                      |
| 0 (0.00%)      | 0             | 0               | 0                        | 0                      |
| 9 (19.15%)     | 2             | 7               | 7                        | 2                      |
| 6 (12.77%)     | 2             | 4               | 4                        | 2                      |

47           11 (23.4%) 36 (76.6%) 30 (63.8%) 17 (36.2%)
Discussion

Knowledge of the head and jaws anatomy is an imperative in dentistry (18). The bifid mandibular canal is one of the most common anatomical variations of the mandibular canal although it is usually ignored and misdiagnosed in dental practice (19). Although panoramic radiographs are commonly used as a preoperative examination tool for dental and oral surgical procedures, they have limitations in detecting some uncommon anatomical and morphological BMC variations. This study revealed a prevalence of 4.66%, which is comparable to several studies on the topic (14, 16, 19), however, the reported prevalence in the available literature varies from 0.08 to 8.3%, depending on the used radiological diagnostic tool (7-10, 20-25). The prevalence of 4.66% in this study is much higher than the prevalence of 0.35% reported by Sanchis et al. (21), 0.9% reported by Nortje et al. (7) and the prevalence of 0.95% reported by Langlais et al. (10). These differences in values may be explained by the quality of the examination technique used to detect BMC and the observers’ experience. The studies that reported low prevalence of BMCs (less than 1%), used conventional panoramic radiographs. Digital radiographs, which were used as a diagnostic tool in this study, definitely enabled better precision and clarity of the image (7, 10, 20). The studies that reported a prevalence similar to the one obtained in this study, also used digital radiographs, e.g. study by Haas et al. (16), Schilling et al. (23) and Andrade et al. (14) who reported the prevalence of 4.2%, 5.0% and 5.3%, respectively. However, the studies with CBCT imaging and BMC identification showed a much higher prevalence (from 10 to 65%) (7-10). The utilization of digital panoramic radiographs in order to detect BMCs has some objective disadvantages compared to CBCT scans. However, by using the most commonly used diagnostic tool in dentistry, we aimed to assess the possibilities of diagnosing BMCs on digital panoramic radiographs.

No statistically significant difference was found between males and females and BMC prevalence in this and several other studies with a sample size ranging from several hundred

Table 3. Types of bifid mandibular canals (BMCs)

| Type of BMC • Tip DMK | Description • Opis |
|-----------------------|--------------------|
| Type 1 • Tip 1        | Unilaterally/bilaterally start as a mandibular foramen and immediately divides into two separate canals. One canal ends in the third molar region and the other as a mental foramen. Unilateral/bilaterial canal počinju dvama快速增长 mandibularnim otvorom i dijeli se na dva odvojena kanala. Jedan završava u regiji trećeg molata, a drugi kao mentalni otvor. |
| Type 2 • Tip 2        | Unilaterally/bilaterally starts as a mandibular foramen, immediately divides into two separate canals. The canals rejoin in the ramus or corpus of the mandible and end as a single canal as a mental foramen. Unilateral/bilateral canal počinju dvama zasebnim mandibularnim otvorom koji se zatim spajaju u jedinstveni, široki mandibularni kanal. |
| Type 3 • Tip 3        | Combination of Types 1 on one side and 2 on the other. Kombinacija tipa 1 s jedne i tipa 2 s druge strane |
| Type 4 • Tip 4        | Unilaterally/bilaterally starts as two separate mandibular foramina and then merge into a single, broad mandibular canal. Unilateral/bilateral kanali počinju dvama zasebnim mandibularnim otvorom i završavaju se kao čvrst mandibularni kanal. |
| Type 5 • Tip 5        | Unilaterally/bilaterally starts as a mandibular foramen and ends with two separate mental foramina. Unilateral/bilateral kanali počinju i završavaju dvama odvojenim mentalnim otvorima. |
| Type 6 • Tip 6        | Unilaterally/bilaterally starts as a mandibular foramen; one branch separates from the main canal and ends in the angle of the mandible, while the second branch ends with a mental foramen. Unilateral/bilateral kanal počinje zajedničkim mandibularnim otvorom, nakon čega se jedna grana odvaja od glavnoga kanala i završava u kutu mandibule, a druga završava kao mentalni otvor. |

Rasprava

Poznavanje anatomije glave i čeljusti veoma je važno u dentalnoj medicini (18). Dvostruki mandibularni kanal jedna od najčešćih anatomskih varijacija mandibularnoga ka- nal, premda se u svakodnevnoj praksi često zanemaruje i pogođeno dijagnosticira (19). Iako su ortopantomogramske snimke najčešći alat prije dentalnih i oralno-kirurških za- hvata, imaju određena ograničenja u detektiranju nekih ne- uobičajenih anatomskih i morfoloških varijacija DMK-a. U ovom istraživanju utvrdili smo učestalost DMK-a od 4,66 %, što se može usporediti s rezultatima nekoliko sličnih stu- dija (14, 16, 19), no objavljena učestalost u dostupnoj lite- raturi varira od 0,08 do 8,3 %, ovisno o vrsti analiziranih radioloških dijagnostičkih snimki (7 – 10, 20 – 25). Uče- stalost od 4,66 % u ovom istraživanju dosta je viša od uče- stalosti od 0,35 % o kojoj su izvijestili Sanchis i suradni- ci (21), 0,9 % o čemu su izvijestili Nortje i suradnici (7) te učestalosti od 0,95 % koju su objavili Langlais i suradnici (10). Te razlike u vrijednostima mogu se objasniti kvalite- tom tehnike snimanja koja se koristi za otkrivanje DMK-a i iskustvom promatrača. Studije koje su izvijestile o nižoj učestalosti DMK-a (manje od 1 %) koristile su se konvencio- nalnim ortopantomogramima. Digitalni ortopantomogra- mi, koji su koristeni kao dijagnostički alat u ovom istraživa- nju, sigurno su omogućili veću preciznost i jasnoću slike (7, 10, 20). Studije u kojima su autorii izvijestili o učestalosti sličnoj onoj u ovom istraživanju, također su se koristili di- gitalnim ortopantomogramima, na primjer Haas i suradni- ci (16), Schilling i suradnici (23) i Andrade i suradnici (14) koji su izvijestili o učestalosti od 4,2 %, 5,0 % i 5,3 %, re- trospektivno. No istraživanja provedena na temelju CBCT snimki pokazuju mnogo veću učestalost DMK-a (od 10 do 65 %) (7 – 10). Korištenje digitalnih ortopantomograma za otkrivanje DMK-a ima objektivne nedostatke u usporedbi s CBCT snimanjem, no kako je to najčešće koristen dija- nostički alat u dentalnoj medicini, nastojali smo procijeni- ti mogućnosti dijagnosticiranja DMK-a na digitalnim orto- pantogramima.
up to several thousand examined panoramic radiographs (24-28).

Types 1 and 2, according to Langlais et al. classification (10), were the most common BMC type in several studies. Fuentes et al. (24) in Chilean, Kuczynski et al. (25) and Corr er et al. (20) in Brazilian population reported that the most prevalent variation in their studies was type 1 (67%, 83% and 72.6%, respectively) (20,24,25). Type 2 was the most prevalent variation of BMC in this study (44.68%); furthermore, type 2 was also most frequent in a study by Langlais et al. (10) (USA) (54%) and in the study by Kalantar Motamendi et al. (9) (Iran) (82%). With respect to the above-mentioned studies, it should be noted that, apart from the differences in sample size, ethnic diversity may affect the results. Overall, the results obtained in this study resembled those of Langlais et al. (10) who studied the North American population (44.68 and 54%).

Our study revealed two types of BMCs not described in the BMC classifications available in the literature. We named them type 5 and type 6. Type 5 was referred to as unilateral or bilateral BMC that started from the mandibular foramen and ended with two separate mental foramina. Mahnaz et al. (29) published the case of a 47-year-old male patient who had experienced a persistent dull pain after the root canal treatment. He observed two separate mandibular foramina and canals, which merged into a single canal anteriorly and ended as a single mental foramen on the right side (type 4 according to Langlais et al. (10) classification). On the left side, he observed two separate mandibular foramina and canals which ended as two separate mental foramina, which corresponds to the type 5 described in this study. Along with the type 1 and 2, type 5 was also not uncommon (N = 9; 0.89%).

Type 6 referred to as unilateral or bilateral canal that started from the common mandibular foramen, after which one branch separates from the main canal and ends in the angle of the mandible, while the second branch ends a mental foramen. To the best of our knowledge, type 6 was not previously described in the literature. We have not registered type 4 BMC in our study. Kuczynski et al. also did not register type 4 BMC in their study on 3024 panoramic radiographs (25). An extremely rare anatomical variation of a trifid mandibular canal was not observed in this study. Data on trifid mandibular canals are limited to several case reports (30, 31).

Accessory canals have been implicated in failure to achieve complete anesthesia since 1960, when variations of mandibular canal were identified (32). Based on the available literature, a success rate of the IAN block anesthesia has ranged from 80-92 %. Kaufman et al. have registered a success rate of the IAN block ranging from 80 to 85%, while Keetley and Moles recorded a higher success rate of 91.9%, which was lower than other nerve blocks in the maxilla (33, 34). There are several possibilities for the ineffectiveness of IAN blocks, such as the presence of an acute infection, poor technique and the presence of a morphological and anatomical variation (35-37). Lew and Townsen (17) discussed the failure of obtaining an adequate anesthesia in their case report due to a BMC with two separate mandibular foramina, i.e. the type 4 BMC according to Langlais et al. classification.

Nije pronađena statistički značajna razlika između muškaraca i žena u učestalosti DMK-a u ovoj studiji i u nekoliko drugih s veličinom uzorka od nekoliko stotina do nekoliko tisuća pregledanih ortopantomografskih snimki (24 – 28).

Tipovi 1 i 2, prema klasifikaciji Langlaisa i suradnika (10), bili su najčešći tipovi DMK-a u nekoliko istraživanja. Fuentes i suradnici (24) u čileanskoj populaciji, Kuczynski i suradnici (25) te Correr i suradnici (20) u brazilskoj populaciji izvijestili su da je najčešća varijacija u njihovim istraživanjima bio tip 1 (67 %, 83 % i 72,6 %, retrospektivno). Tip 2 bio je najčešća varijacija DMK-a u ovom istraživanju (44,68 %).

Kaufman i suradnici su registrovali uspješnost anestezije donjega alveolarnog živca u rasponu od 80 do 92 %.

Uporedno s tim, tip 2 je također bio najčešći u istraživanju Langlaisa i suradnika (10) (SAD) (54 %) i u istraživanju Kalantar Motamendi i suradnika (9) (Iran) (82 %). S obzirom na spomenuta istraživanja valja napomenuti da, osim razlika u veličini uzorka, rezultate može utjecati i etnička raznovrsnost. Sveukupno, rezultati dobiveni u ovoj studiji najsličniji su rezultatima istraživanja Langlaisa i suradnika (10) koji su analizirali sjeveroameričko stanovništvo (44,68 i 54 %).

Ovo istraživanje otkrilo je dva nova tipa DMK-a koji dosad nisu opisani u dostupnoj literaturi i nazvali smo ih tip 5 i tip 6. Tip 5 odnosi se na unilateralni ili bilateralni BMC koji počinje mandibularnim otvorom i završava s dvama odvojenim mentalnim otvorima. Mahnaz i suradnici (29) objavili su prizak slučaja 47-godišnjaka koji je nakon liječenja korijskoga kanala trajno osjećao tupu bol na desnoj strani uočio je dva odvojena mandibularna otvora i kanala koji se spažaju u jedan i završavaju kao jedan mentalni otvor (odgovara tipu 4 prema klasifikaciji Langlaisa i suradnika (10)). Na lijevoj strani uočio je dva odvojena mandibularna otvora koji završavaju kao dva odvojena mentalna otvora, što odgovara tipu 5 iz naše istraživanja. Uz tip 1 i tip 2, tip 5 takoder nije bio neobjičen (N = 9; 0,89 %).

Tip 6 odnosi se na unilateralni ili bilateralni BMC koji počinje zajedničkim mandibularnim otvorom nakon čega se jedna grana odvaja od glavnoga kanala i završava u kutu mandibule, a druga završava kao mentalni otvor. Koliko znamo, tip 6 nije do sada bio opisan u dostupnoj literaturi. U našem istraživanju nismo registrirali DMK tip 4. Kuczynski i suradnici također nisu zabilježili DMK tip 4 u svojoj studiji na temelju 3024 ortopantomografa (25). Unutar istraživanja nije uočena iznimno rijetka anatomska varijacija trostruka-ga mandibularnoga kanala. Podatci o trostrukim mandibularnim kanalima ograničeni su na nekoliko prikaza slučajeva (30, 31).

Akcorski kanali povezivani su s neuspješnom anestezijom 1960. godine kada su otkrivena varijacije mandibularnoga kanala (32). Na temelju dostupne literature, uspješnost anestezije donjega alveolarnoga živca kreće se od 80 do 92 %. Kaufman i suradnici zabilježili su stopu uspješnosti anestezije donjega alveolarnoga živca u rasponu od 80 do 85 %, a Kee tley i Moles višu od 91,9 %, što je niže od ostalih anestezija u maksili (33, 34). Nekoliko je mogućih razloga za neuspješnost anestezije donjega alveolarnoga živca, poput akutne infekcije, loše tehnike ubrizgavanja i morfoloških i anatomskih varijacija (35 – 37). Lew i Townsen (17) raspravljali su o neuspješnim anestezijama u svojem prikazu slučaja zbog DMK-a s dvama odvojenim mandibularnim otvorima, tj. o DMK-u ti-
(10). Apart from the type 4, all other BMC types could present an obstacle for an effective IAN block (32, 38). Based on the findings of this and similar studies, it would be interesting to assess the connection between the anatomical variation of BMC and the efficiency of IAN blocks.

Types 1 and 2 by Langlais et al. (10) and type 5 described in this study, probably have the highest risk of IAN injury during tooth extraction, dental implant placement, apicectomy or removal of pathologies in the molar region. The reported frequency of IAN injuries associated with extraction of third molar ranges from 0.4-9.4%, but the risk of permanent IAN injury was reported, which was less than 1% (39-42).

Moreover, types 1, 2 and 5 were the most common types in our study. De Toledo Telles-Araújo et al. (42) did not find CBCT superior to panoramic radiograph in avoiding nerve injuries i.e. neurosensory disturbances following the removal of the mandibular third molar.

Conclusions

This study revealed a relatively high prevalence rate of BMCs. No significant difference was found between males and females with BMC. Type 2 BMC, according to Langlais et al. classification (10), was the most common BMC type. We identified and described two new BMC types, Type 5 and Type 6, previously not described in the available literature.

We identified and described two new BMC types, Type 5 and Type 6, previously not described in the available literature. The types 1, 2 and 5 were the most common types in our study. De Toledo Telles-Araújo et al. (42) did not find CBCT superior to panoramic radiograph in avoiding nerve injuries i.e. neurosensory disturbances following the removal of the mandibular third molar.

Types 1 and 2 by Langlais et al. (10) and type 5 described in this study, probably have the highest risk of IAN injury during tooth extraction, dental implant placement, apicectomy or removal of pathologies in the molar region. The reported frequency of IAN injuries associated with extraction of third molar ranges from 0.4-9.4%, but the risk of permanent IAN injury was reported, which was less than 1% (39-42).

Moreover, types 1, 2 and 5 were the most common types in our study. De Toledo Telles-Araújo et al. (42) did not find CBCT superior to panoramic radiograph in avoiding nerve injuries i.e. neurosensory disturbances following the removal of the mandibular third molar.

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Conflict of Interest

None declared.

Author’s Contribution: A.M., I.S., D.M. - conceptualized, wrote and made the study design; H.M. and K.M. participated in the acquisition of data; P.O., Z.O., I.Z. and D.B. participated in data analysis and interpretation of data. All of the authors substantially contributed to drafting of the article, critical revision and gave their final approval of the version to be submitted.

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