Dentomaxillofacial Radiology (2015) 44, 20150097

birpublications.org/dmfr

RESEARCH ARTICLE

Ultrasound analysis of mental artery flow in elderly patients: a case–control study

[1]Marina G Baladi, [1]Raul R C M Tucunduva Neto, [2,3]Arthur R G Cortes, [1]Eduardo M Aoki, [1]Emiko S Arita and [1]Claudio F Freitas

[1]Oral Radiology Division, School of Dentistry, University of Sao Paulo, Sao Paulo, Brazil; [2]Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Charlestown, MA, USA; [3]Department of Radiology, Harvard Medical School, Boston, MA, USA

Objectives: Mental artery flow decreases with age and may have an aetiological role in alveolar ridge atrophy. The aim of this study was to identify factors associated with alterations of mental artery flow, assessed by ultrasonography.
Methods: This case–control study was conducted on elderly patients (aged above 60 years) at the beginning of dental treatment. Intraoral B-mode Doppler ultrasonography was used to assess mental artery flow. The cases were defined as patients with a weak/absent ultrasound signal, whereas the controls presented a strong ultrasound signal. Demographics and radiographic findings (low bone mineral density on dual-energy X-ray absorptiometry and mandibular cortical index on panoramic radiographs) were analysed as risk factors for weak/absent ultrasound signal and were calculated as adjusted odds ratios (AORs) with 95% confidence intervals (CIs) using conditional logistic regression. In addition, the Student's *t*-test was used to compare the mean alveolar bone height of the analysed groups. A p-value <0.05 was considered statistically significant.
Results: A total of 30 ultrasound examinations (12 cases and 18 controls) were analysed. A weak/absent mental artery pulse strength was significantly associated with edentulism (AOR = 3.67; 95% CI = 0.86–15.63; $p = 0.046$). In addition, there was a significant difference in alveolar bone height between edentulous cases and controls ($p = 0.036$).
Conclusions: Within the limitations of this study, the present results indicate that edentulism is associated with diminished mental artery flow, which, in turn, affects alveolar bone height.
Dentomaxillofacial Radiology (2015) **44**, 20150097. doi: 10.1259/dmfr.20150097

Cite this article as: Baladi MG, Tucunduva Neto RRCM, Cortes ARG, Aoki EM, Arita ES, Freitas CF. Ultrasound analysis of mental artery flow in elderly patients: a case–control study. *Dentomaxillofac Radiol* 2015; **44**: 20150097.

Keywords: Doppler ultrasonography; mental artery; edentulism

Introduction

Blood supply is a determinant factor affecting the healing process. Compromised vascularization may lead to alterations in bone remodelling capacity and integrity.[1] In addition, blood flow assessment is critical in establishing the diagnosis of several pathological conditions.[2,3]

Correspondence to: Arthur R G Cortes. E-mail: acortes@nmr.mgh.harvard.edu
A post-doctoral scholarship was granted to ARGC by the National Council for Scientific and Technological Development (CNPq)—Science without Borders, Brazil, no. 232643/2013-0.
Received 17 March 2015; revised 12 June 2015; accepted 23 July 2015

One method to assess blood supply is ultrasonography. This is a versatile, painless and non-invasive method of imaging diagnosis that does not use ionizing radiation. It can acquire sectional images of anatomic structures in any spatial orientation.[4] In addition, Doppler ultrasonography effect enables assessing haemodynamics, which includes dynamic features of both vascular architecture and blood flow in real time.[5]

The diagnostic potential of ultrasonography in dentistry has been described in the literature.[4–9] Applications include oral cancer diagnosis,[2,10] salivary gland imaging[6,11] and assessment of mandibular vascularization. The mandibular vascularization is useful to detect blood flow changes in the inferior alveolar artery and its branches, as well as in the mental artery, which exits the mandible through the mental foramen.[12]

It has been established that the mental artery flow diminishes with age.[7,8] This condition has been described as a potential aetiological factor for alveolar bone atrophy.[7] However, little is known regarding factors associated with decreased mental artery flow and its influence on mandibular ridge atrophy.

Thus, the purpose of this study was to identify factors associated with the alterations of mental artery flow and to assess the association between mental artery flow and residual alveolar bone height.

Methods and materials

This case–control study was initiated after approval of the project by the Ethics Committee (Protocol Number: 166.119). All patients willing to participate in this study signed an informed consent form. The strengthening the reporting of observational studies in epidemiology (STROBE) guidelines for observational studies and the guidelines of the Helsinki Declaration were followed in this investigation.

Inclusion and exclusion criteria

Elderly patients (aged above 60 years) presenting for dental treatment in the clinic of this study were enrolled consecutively from May 2012 to August 2013. All patients included had previously undergone body mass index assessment and low-density lipoprotein cholesterol screening test. In addition, the selected patients presented either a totally edentulous (with over 5 years of edentulism) or totally dentulous (*i.e.* at least from the first molar to the first molar) mandible.

Edentulous patients with a recent tooth extraction (less than 6 months of follow-up) were excluded to avoid the imprecision of the socket remodelling period. Patients with any blood or metabolic disorders, such as diabetes and vitamin D deficiency, or with a history of radiotherapy, were also excluded.

Radiographic analyses

Digital panoramic radiographs (Veraviewepocs® 2D; Morita, Tokyo, Japan) of all the patients were taken at the beginning of the dental treatment, as an examination recommended for general screening.[13] Images were taken using the following exposure conditions: 60 kV, 4 mA, 0.5-mm copper filter and were analysed using an imaging processing software program (ImageJ®, National Institute of Health, Bethesda, MD). Images were corrected using a magnification factor of 1.3, and spatial calibration was set at a scale of 1 pixel per 96 μm.

The mandibular cortical index was assessed by evaluating the appearance of the inferior mandibular cortex below the mandibular foramen, using a classification system described in the literature.[14] In brief, the inferior mandibular cortex was classified as "C1" or normal, when presenting an even and distinct endosteal margin, "C2" or moderately eroded, when presenting evidence of lacunar resorption or endosteal cortical residues, and "C3" or severely eroded, when unequivocal porosity was observed.

In addition, the alveolar bone height of totally edentulous patients ($n = 15$) was measured from the mental foramen to the alveolar crest, using the linear measurement tool of the above mentioned software program, following a methodology described in the literature.[15]

All panoramic radiographic measurements were performed in random order by two trained observers (*i.e.* dentists with expertise in oral radiology). Intraobserver reliability was assessed between measurements performed 2 weeks apart to eliminate memory bias. Intraobserver and interobserver agreements were assessed using the kappa test for mandibular cortical index assessment and intraclass correlations coefficient for alveolar bone height measurements.

All patients also underwent a dual-energy X-ray absorptiometry examination of the forearm. Bone mineral

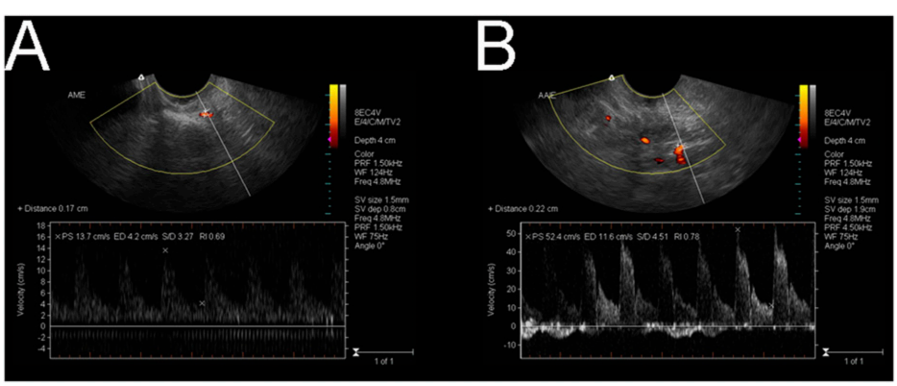

Figure 1 Images produced by the ultrasound system. (a) Capture of weak/absent Doppler ultrasound signals (cases). Systolic velocity is not clearly depicted in the spectral Doppler time–velocity graph. (b) Capture of strong Doppler ultrasound signals (controls). The examination produced a clearly visible spectral Doppler time–velocity graph, providing numerical data to assess systolic peak velocity in real time.

density (BMD) (in grams per square centimetre) was measured at the distal radius with a bone densitometer (Norland pDEXA; Norland Medical Systems, White Plains, NY), according to the manufacturer's recommendations.

B-mode Doppler ultrasound measurements

All ultrasound images were obtained with a portable device (Terason t3000™; Terason Ultrasound, Burlington, MA), using an intraoral endocavitary transducer (model 8EC4; Terason Ultrasound; variable frequency 4–8 MHz; Figure 1). A physician with over 20 years' experience in ultrasonography performed the examination intraorally on all patients, following a methodology described in the literature.[16] In brief, the intraoral endocavitary transducer was set with an 8-MHz probe. A latex casing (Madeitex®; Madeitex Ind. e Com. de Artefatos de Látex Ltda, São José dos Campos, Brazil) was used with acoustic gel to protect the transducer. The probe was then placed in the mucobuccal fold overlying the mental neurovascular bundle. A B-mode Doppler ultrasonography was performed only on the buccal side, in the sagittal plane, to detect any signal from blood flow through the mental artery on the right and left sides of the patient. Power Doppler settings were standardized and optimized to obtain maximum sensitivity for low-velocity flows, with a pulse repetition frequency of 1000 Hz, a low-pass wall filter, medium persistence and a Doppler gain set to maximal values below threshold. The real-time images were produced and evaluated on the monitor of the ultrasound device. Pulse strength was obtained and classified into cases and controls according to the output pattern of the ultrasound device.[7]

To confirm the reproducibility of our methodology, two pilot sets of ultrasound examinations were performed in representative patients, 2 weeks apart from each other to eliminate memory bias. A radiologist with expertise in ultrasound served as the second examiner. Intraobserver and interobserver agreements were assessed using the kappa test.

Case and control definitions

When the signal was absent or insufficient to produce numerical data to quantify systolic peak velocity, pulse strength was classified as weak/absent (cases; Figure 1a). Similarly, when the signal was strong enough to produce numerical data to assess systolic peak velocity in the spectral Doppler time–velocity graph, pulse strength was classified as strong (controls; Figure 1b).[7]

Statistical analysis

The sample size was determined using the uncorrected χ^2 test, to detect a minimum odds ratio of 5, and to give the study a power of 80%, at a level of significance of 5%. Conditional logistic regression was used to assess associations between ultrasound pulse strength signal and the rest of the variables. All variables were stratified using cut-off points. Risk estimates were presented as odds ratios with 95% confidence intervals. The odds ratios were adjusted for potential confounders of age and gender. Finally, the Student's *t*-test was also used to compare age and mean alveolar bone height between edentulous cases and controls. A p-value <0.05 was considered statistically significant. All statistical analyses were performed using the IBM SPSS Statistics 17 software (IBM Corp., New York, NY; formerly, SPSS Inc., Chicago, IL).

Results

A total of 30 ultrasound examinations (12 cases and 18 controls) were included in the study (Figure 1). The case group had a mean age of 60.6 ± 9.8 years, whereas the control group had a mean age of 55.8 ± 11.9 years. The difference in age between both groups was not statistically significant ($p > 0.05$).

Intraobserver reproducibility and interobserver reliability were confirmed for the mandibular cortical index assessment (kappa between 0.78 and 0.90; $p = 0.001$), as well as for alveolar bone height measurements (intraclass correlations coefficient between 0.82 and 0.94; $p = 0.001$). In addition, perfect intraexaminer and interexaminer agreements were found for detection of pulse strength on ultrasound examinations (kappa = 1; $p = 0.001$).

Statistical analysis showed that edentulism (adjusted odds ratio = 15.10; 95% confidence interval = 2.07–116.02; $p = 0.009$) was significantly associated with weak/absent mental artery pulse strength (Table 1). All other factors were not significantly associated with mental artery pulse strength ($p > 0.05$). In addition, there was a significant difference in alveolar bone height between edentulous cases (mean of 4.77 ± 1.66 mm) and controls (mean of 7.27 ± 3.72 mm), according to the Student's *t*-test ($p = 0.036$).

Discussion

The blood supply of the mandible comes mainly from two sources: internally from the inferior alveolar artery and externally from the periosteum, covering the mandible.[12] However, the periosteum has been regarded as responsible mainly for preventing mandibular ridge atrophy, owing to the cortical nature of the mandibular bone.[17] By contrast, our results indicate that internal vascularization is also associated with mandibular ridge atrophy, as suggested by a similar study.[7] Furthermore, as previously described,[16] the assessment of the mental artery flow, as performed in this study, is useful to predict internal vascularization of the mandible, since the mental artery is a continuation of the inferior alveolar artery.

Only elderly patients were included in our study sample; therefore, our analyses could be initially adjusted to the confounding factor of age. In addition, most of the elderly dentulous patients analysed presented a strong ultrasound signal of mental artery flow. This finding contrasts with other studies[7,8,18] suggesting an inverse relationship between mental artery flow and the patients' age. Furthermore, the present study also strove to evaluate the association between osteoporotic alterations and mental artery flow.

Table 1 Risk estimates for association with weak/absent mental artery pulse strength

	Mental artery pulse strength			
Variables	*Weak/absent*	*Strong*	*AOR (95% confidence interval)*	p-*value*
Body mass index (kg m^{-2})				
≤25	4	7	1	
>25	8	11	3.04 (0.36–25.99)	0.310
Low-density lipoprotein cholesterol (mg dl^{-1})				
≤130	8	16	1	
>130	4	2	6.53 (0.41–103.61)	0.183
Bone mineral density				
Normal	9	11	1	
Low	3	7	0.47 (0.06–3.57)	0.463
Edentulism				
No	2	13	1	
Yes	10	5	15.10 (2.07–116.02)	0.009[a]
Mandibular cortical index				
C1/C2	6	11	1	
C3	6	7	2.62 (0.29–23.20)	0.387

AOR, adjusted odds ratio for the confounders: age and gender.
[a]Statistically significant ($p < 0.05$).

Despite the relation between lack of bone marrow perfusion and osteoporosis, described in the literature,[19] no relation was found between low BMD and diminishing mental artery flow, in agreement with another similar study.[8]

On the other hand, one limitation of the present study is that dual-energy X-ray absorptiometry values for BMD were taken from the forearm, whereas the lumbar spine is considered the gold standard method for obtaining *T*-score (BMD measurement compared with a young adult reference population) and *Z*-score (BMD measurement compared with an age-matched reference population), in accordance with the World Health Organization.[20] Furthermore, while the case–control design of the present study allows for the assessment of risk associations, future cohort studies with larger sample sizes are needed to determine the causality of a decreasing mental artery flow and mandibular ridge atrophy, as well as the biological and genetic factors associated with these alterations.

Another limitation of this study is that the alveolar bone height was measured with panoramic radiographs, which are less accurate than CT scans for performing linear measurements.[21] Future research with CT scans would be required to compare standardized measurements on different sites of the mandible. On the other hand, the rationale of using digital panoramic radiographs was to provide data from a commonly available examination used for general screening at the patients' first visit,[13] in accordance with the "as low as reasonably achievable" guidelines of radiation safety.[22]

Conclusions

In conclusion, within the limitations of this study, the present results indicate that edentulism and mandibular ridge atrophy are associated with diminished mental artery flow.

Acknowledgments

We would like to thank Prof. Dr Marlene Fenyő Soeiro Pereira de Matos, for her encouragement and support. The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

References

1. McGregor AD, MacDonald DG. Post-irradiation changes in the blood vessels of the adult human mandible. *Br J Oral Maxillofac Surg* 1995; **33**: 15–18. doi: 10.1016/0266-4356(95)90079-9
2. Kagawa T, Yuasa K, Fukunari F, Shiraishi T, Miwa K. Quantitative evaluation of vascularity within cervical lymph nodes using Doppler ultrasound in patients with oral cancer: relation to lymph node size. *Dentomaxillofac Radiol* 2011; **40**: 415–21. doi: 10.1259/dmfr/18694011
3. Koelemay MJ, den Hartog D, Prins MH, Kromhout JG, Legemate DA, Jacobs MJ. Diagnosis of arterial disease of the lower extremities with duplex ultrasonography. *Br J Surg* 1996; **83**: 404–9. doi: 10.1002/bjs.1800830336
4. Jones JK, Frost DE. Ultrasound as a diagnostic aid in maxillofacial surgery. Report of a case. *Oral Surg Oral Med Oral Pathol* 1984; **57**: 589–4. doi: 10.1016/0030-4220(84)90277-9
5. Bavitz JB, Harn SD, Homze EJ. Arterial supply to the floor of the mouth and lingual gingiva. *Oral Surg Oral Med Oral Pathol* 1994; **77**: 232–5. doi: 10.1016/0030-4220(94)90290-9
6. Carotti M, Salaffi F, Manganelli P, Argalia G. Ultrasonography and colour doppler sonography of salivary glands in primary Sjögren's syndrome. *Clin Rheumatol* 2001; **20**: 213–19. doi: 10.1007/s100670170068
7. Eiseman B, Johnson LR, Coll JR. Ultrasound measurement of mandibular arterial blood supply: techniques for defining ischemia in the pathogenesis of alveolar ridge atrophy and tooth loss in the elderly? *J Oral Maxillofac Surg* 2005; **63**: 28–35. doi: 10.1016/j.joms.2003.05.024
8. Klein MO, Grötz KA, Manefeld B, Kann PH, Al-Nawas B. Ultrasound transmission velocity for noninvasive evaluation of jaw bone quality *in vivo* before dental implantation. *Ultrasound Med Biol* 2008; **34**: 1966–71. doi: 10.1016/j.ultrasmedbio.2008.04.016

9. Lustig JP, London D, Dor BL, Yanko R. Ultrasound identification and quantitative measurement of blood supply to the anterior part of the mandible. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003; **96**: 625–9. doi: 10.1016/S107921040300516X
10. Yuasa K, Kawazu T, Nagata T, Kanda S, Ohishi M, Shirasuna K. Computed tomography and ultrasonography of metastatic cervical lymph nodes in oral squamous cell carcinoma. *Dentomaxillofac Radiol* 2000; **29**: 238–44. doi: 10.1038/sj/dmfr/4600537
11. Oeppen RS, Gibson D, Brennan PA. An update on the use of ultrasound imaging in oral and maxillofacial surgery. *Br J Oral Maxillofac Surg* 2010; **48**: 412–18. doi: 10.1016/j.bjoms.2009.10.022
12. Castelli W. Vascular architecture of the human adult mandible. *J Dent Res* 1963; **42**: 786–92. doi: 10.1177/00220345630420030701
13. Rushton VE, Horner K, Worthington HV. Factors influencing the selection of panoramic radiography in general dental practice. *J Dent* 1999; **27**: 565–71. doi: 10.1016/S0300-5712(99)00031-7
14. Arita ES, Pippa MG, Marcucci M, Cardoso R, Cortes AR, Watanabe PC, et al. Assessment of osteoporotic alterations in achondroplastic patients: a case series. *Clin Rheumatol* 2013; **32**: 399–402. doi: 10.1007/s10067-012-2126-x
15. Yüzügüllü B, Gulsahi A, Imirzalioglu P. Radiomorphometric indices and their relation to alveolar bone loss in completely edentulous Turkish patients: a retrospective study. *J Prosthet Dent* 2009; **101**: 160–5. doi: 10.1016/S0022-3913(09)60021-4
16. Ethunandan M, Birch A, Evans BT, Goddard JR. Doppler sonography for the assessment of central mandibular blood flow. *Br J Oral Maxillofac Surg* 2000; **38**: 294–8. doi: 10.1054/bjom.1999.0304
17. Chanavaz M. Anatomy and histophysiology of the periosteum: quantification of the periosteal blood supply to the adjacent bone with 85Sr and gamma spectrometry. *J Oral Implantol* 1995; **21**: 214–19.
18. McGregor AD, MacDonald DG. Age changes in the human inferior alveolar artery–a histological study. *Br J Oral Maxillofac Surg* 1989; **27**: 371–4. doi: 10.1016/0266-4356(89)90075-2
19. Griffith JF, Yeung DK, Tsang PH, Choi KC, Kwok TC, Ahuja AT, et al. Compromised bone marrow perfusion in osteoporosis. *J Bone Miner Res* 2008; **23**: 1068–75. doi: 10.1359/jbmr.080233
20. Celi M, Rao C, Scialdoni A, Tempesta V, Gasbarra E, Pistillo P, et al. Bone mineral density evaluation in osteoporosis: why yes and why not? *Aging Clin Exp Res* 2013; **25**(Suppl. 1): S47–9. doi: 10.1007/s40520-013-0074-1
21. Hedeşiu M, Balog C, Preda DM, Băciuţ M, Fildan F, Pop A, et al. The accuracy of alveolar crest dimensions measurement for dental implants. *In vitro* study. *Rev Med Chir Soc Med Nat Iasi* 2008; **112**: 224–8.
22. Dykstra BA. ALARA and radiation in the dental office: current state of affair. *Dent Today* 2011; **30**: 14, 16, 18.