Evaluation of telemedicine in the management of dentogenous infections
Procena primene telemedicine u zbrinjavanju dentogenih infekcija

Milan Miladinović*, Dragan Mladenović†, Branko Mihailović*, Goran Tošić†,
Boris Djndjić, Sanja Mladenović†, Mervan Hadžibetić†, Biljana Vujčić†

* Dentistry Clinic, Faculty of Medicine, University of Priština/Kosovska Mitrovica,
Kosovska Mitrovica, Serbia; † Dentistry Clinic, Faculty of Medicine, University of Niš,
Niš, Serbia; ‡ Dental Office “Ulcinj”, Ulcinj, Montenegro

Abstract
Introduction/Aim. The first written evidence of telemedicine dates back to the times of Sava Nemanjić (the end of 12th and the beginning of 13th century). Nowadays, the use of telemedicine in Serbia gains momentum, and the cause of this lies in the creation of a central telemedicine system XPA3 Online and the establishment of the Center for Telemedicine at the Faculty of Medicine, University of Priština/Kosovska Mitrovica, Kosovska Mitrovica, Serbia. Dentogenous infections are among the most urgent conditions in dentistry, which may have even a fatal outcome. The aim of this study was to assess the possibility of using telemedicine methods in the pathology of dentogenous infections. Methods. This experimental randomized study included 414 patients with suspected dentogenous infection. The patients were enrolled at 7 sites, with systematic photograph-taking, collection, and digitalization of the available anamnestic and laboratory data, tests, and x-rays. Together with clinical findings, the data were uploaded on the XPA3 Online central telemedicine system; after that, 10 teleconsultants reviewed the material, set the diagnosis, and gave their opinion about the treatment. The agreement was determined using the Cohen's kappa (κ) coefficient, as well as diagnostic sensitivity (SE), specificity (SP), and efficacy (EFF). Statistical significance and comparisons were done using the z-test, and testing non-parametric properties using the McNemar’s χ²-test for the significance threshold of p = 0.05. Results. The results describing agreement of telemedicine diagnosis of the areas primarily involved with infection compared to clinical inspection, indicate an almost complete diagnostic agreement (κ = 0.971). Diagnostic agreement as to the type of infection was also almost complete (κ = 0.951), and a similar value was obtained also for the treatment agreement (κ > 0.892). Conclusion. The method of telemedicine provides us with a tool to make a correct clinical diagnosis of dentogenous infections equally well as in real time, as well as to get a deeper and wider insight into their nature and to suggest adequate treatments.

Key words:
dental informatics; remote consultation; focal infection, dental; treatment outcome.

Apstrakt
Uvod/Cilj. Prvi zapisi o primeni telemedicine u Srbiji datiraju iz vremena Save Nemanjića (kraj XII i početak XIII veka). Danas, primena telemedicine u Srbiji naglo raste, a uzrok leži u stvaranju centralnog teledemetskog sistema XPA3 Online i formiranju teledemetskog centra Medicinski fakulteta Univerziteta u Prištini/Kosovska Mitrovica, Srbija. Takođe, dentogene infekcije spadaju u najuzorljivije stanja u stomatologiji, koja mogu da imaju i letašan ishod. Cilj rada bio je da se ispitaju mogućnosti primene telemedicine kod patologije dentogenih infekcija. Metode. Urađena je eksperimentalna randomizirana studija na 414 pacijenata kod kojih je postojala sumnja na pristup st stomatološkoj infekciji. Pacijenti su primani na sedam lokacija, pri čemu su radena sistematska fotografisanja, sakupljanje i digitalizacija dostupnih anamnestičkih i laboratorijskih nalaza, testova, kao i radioloških snimaka. Sve je to zajedno sa kliničkim nalazozm proslavljeno na XPA3 Online centralni teledemetski sistem, nakon čega su deset telekonsultanata pregledali materijal, postavljali dijagnozu i dvalali terapijsko mišljenje. Određena je saglasnost Cohenovim kappom (κ) koeficijentom, dijagnostička senzitivnost (SE), specifičnost (SP) i efikasnost (EFF). Statistička značajnost i poređenja vršena su z-testom, a testiranje neparametarskih obeležja Mnêmmerovim χ² kvadrat testom za prag značajnosti od p = 0.05. Rezultati. Rezultati slaganja teledemetskih dijagnoza primarno zahvaćena strometologski infekcije u poređenju sa kliničkim pregledom ukazuju na postignutu skoro potpunu dijagnostičku saglasnost (κ = 0.971). Slaganje za vrstu infekcije ukazuje takođe na skoro potpunu dijagnostičku saglasnost (κ = 0.951), a o predloženoj terapiji slaganje je slično (κ = 0.892). Zaključak. Primenom telemedicine može se podjednako dobro, kao i kliničkim pregledom u realnom vremenu, postaviti ispravna dijagnoza infekcije, sagledati njihova problematika i mogućnosti terapije.

Correspondence to: Milan Miladinović, Dentistry Clinic, Dept. of Oral Surgery, Faculty of Medicine in Priština – Kosovska Mitrovica, Anri Dinana street, 38 220 Kosovska Mitrovica, Serbia. Phone: +381 28 498 298. E-mail: milanbetter@gmail.com
Introduction

The first evidence about distant medical consultations (teleconsultations) in the history of Serbia dates back to the time of Sava Nemanjić (the end of 12th and the beginning of 13th century), and writings described two such cases: immediately before the resignation of the Grand Prince Nemanja and succession of the throne by his middle son Stefan, Nemanja fell seriously ill, and his delegation was sent to Sava, his youngest son, a monk in the Hilandar Monastery (Mount Athos, Greece) to come and spend his father’s last hours with him. Instead, Sava gave the instructions to the delegates which herbs his father was to take, what to do, and how to pray; in short, he did not come back with them. Firmly believing in the consultation given and praying to the Holy Mountain Protectors, he sent a message to his father to transfer power to the next generation as soon as he was well again, to join Sava on the Holy Mountain and repent for the sins made in worldly life and while in power, and to devote his life to the living God and Holy Mother of God. The success of this teleconsultation was proven by the rapid recovery of Nemanja, his becoming a monk, and permanent moving to the Holy Mountain to join his son Sava. The second distant consultation occurred when Sava’s brother, King Stephan fell ill while Sava was abroad. Sava gave his instructions to the brother’s messengers, which successfully cured him, accompanied by prayers, and Sava himself came later on to see the healing of the future monk Simon.

In 2011 telemedicine in Serbia rapidly developed, triggered by the creation and initial use of the central telemedicine system XPA3 Online (XPA3 Online, Niš, Serbia) and by the foundation of the Telemedicine Center of the Faculty of Medicine University of Priština/Kosovska Mitrovica, Serbia. The system is based on one of the most up-to-date telemedicine systems in the world with the Telemedicine Center of the Faculty of Medicine University of Priština/Kosovska Mitrovica, Serbia. The system is based on one of the most up-to-date forms of application services, with ultra high speed Internet above, and Microsoft Windows 2008 R2 OS and Microsoft SQL Server 2008 R2 data base below. The system manages and co-ordinates provider services for short message service (SMS) information, for rapid and short phone calls, automated receipt and processing of photographs, images, various text formats (.docx., .pdf, .html, .txt), automated conversion of video formats (.mp4., .avi,. mov i dr.) into the widely accepted .flv format, and also receives almost whole patient history. The system is accompanied by a number of ready physicians of almost all specialties, most of which are teachers, associates, principal physicians, and so on. If a physician needs specialist help or interspecialist consultation, he posts a telemedicine request using his/her personal computer or Internet-connected smartphone, and gets the requested consultation in time. In addition to its ability to offer up-to-date and rapid teleconsultation support, the system is equipped with the peripherals for scientific monitoring and analysis, providing researchers with already processed data and access resources. Based on such support of an artificial intelligence system on XPA3 Online, we were able to obtain, in an economical way, a number of results describing the quality of Internet-based telemedicine consultation in different areas of interest.

On the other hand, dentogenous infections represent one of the most urgent conditions in the practice of dentistry, the management of which requires proper training and collaboration of different specialties and which, if managed inadequately or late, can lead even to a fatal outcome. Since such patients require a prompt response and permanent specialist observation, the problem of patient management in cases of inaccessibility of adequate specialist services should be resolved. These situations involve e.g. soldiers in the field, bed-ridden or immovable individuals, those with special needs, individuals in remote and unaccessible geographical areas, or physical inaccessibility of specialists from any reason. We have had the situations that, due to restricted traffic in the region of Kosovo and Metohija, the patients with dentogenous infections could not reach the specialists of oral surgery/otorhinolaryngology/maxillofacial surgery, and their management had to be undertaken by untrained dentists/physicians; the posttreatment recovery was controlled from a distance.

Having knowledge about the natural course of inadequately treated or untreated dentogenous infections, and bearing in mind the possibility of infection spread into the adjacent anatomical spaces, thus creating most severe disease forms and complications (such as Angina Ludovici or cavernous sinus thrombosis), there is the question of how and to what extent the physicians in distant areas (assisted by modern telemedicine systems) can help in the management of such cases. In particular, there is the question of reliability of distant diagnosis and treatment plan in patients with dentogenous infections.

The aim of this study was, therefore, to assess the possibility of using of modern telemedicine methods in the management of patients with dentogenous infections and find an answer if we can make a clinically reliable diagnosis, and evaluate the primary treatment indicated in such cases (extraction of the causal tooth, incision, need for hospital admission and antibiotic therapy administration).

Methods

This experimental randomized study enrolled 414 patients, aged 12 to 83 years, of both genders, with suspicious dentogenous infection as assessed by the physician in charge. The patients were clinically admitted at 4 main sites in Serbia: Kosovska Mitrovica, Niš, Belgrade, Novi Sad, two sites in Bosnia and Herzegovina (Republic of Srpska: Banja Luka and Trebinje), and in Montenegro (Podgorica). They were all clinically examined by the specialists in oral surgery, otorhinolaryngology, and maxillofacial surgery.

Depending on the quality of equipment, analog ortopans were used with the Tubus 85kV R 76 20 15 mA 50–60 Per, filter 1,2 mm AI image quality, the recordings of which were digitalized into JPEG 2048 × 1536 before transmission, while digital ortopans with the image quality 19 sec/10 mAs at 63–81 kV were stored in TIFF 998 × 494. Digital cameras and mobile phones are used to photograph. The patients had cameras with the resolution from 3.1 to 8.0 megapixels. The patients were photographed en face and

bilaterally (en face with head turned upwards, bilaterally with head maximally extended backwards and to the side); extraoral edema was also photographed, if present; inner structures of the mouth cavity, and upper and lower jaw teeth were photographed in the extent possible using only digital camera (without any additional tools for intraoral photography); intraoral edema was also photographed, if present. In summary, each of the patients had ortopan taken, as well as the above photographs. The data were stored either in the physicians’ PCs or in their smartphones. The physicians accessed the Internet via their PCs or smartphones in different ways (ADSL access with 512/128 kbps to 6/1 mbps; global municipal wireless connection at 5 GHz at 2/2 mbps; or via standard mobile access, WCDMA 3G and HSDPA 3G UMTS, with EDGE access if there were no 3G networks). After a successful Internet connection, they accessed the application system of the Center for Telemedicine, University of Pristina/Kosovska Mitrovica (www.xpa3.com) and passed the authentication and authorization phases (protected with a 128 bit Secure Sockets Layer (SSL) security protocol.

Opening a new digital telemedicine request, the physicians entered patient personal information, patient history, as well as the available anamnestic information such as laboratory findings, hospital discharge documents, and other relevant patient data. Attached to the request, there were the files containing photographs and x-rays, together with proper clinical findings, both general and individual, accompanying each of the images. Such a teledentistry request was then sent to the system, and the system in a minute contacted specialist teleconsultants (TCs) with SMS messages, and some of them, additionally, were contacted by phone. Each of the teleconsultants had in the received SMS message the subject of teleconsultation, assessed request urgency (describing the levels as normal or urgent), and expected time to response (30 minutes to 6 hours, depending on the case). Teleconsultants then accessed the Internet system at www.xpa3.com, reviewed the received request, and responded giving their opinion, suggestion, and possible outcome of recommended therapy. Each of the patients was clinically examined, with diagnosis being made in real time (Figures 1, 2).

The degree of diagnostic accuracy was determined using the following scale: correct – if a teledentistry diagnosis is identical to the primary one, or if it is made and is acceptable as a differential diagnosis, and incorrect – if a teledentistry diagnosis differs completely from the primary one, or if the diagnosis has not been made.

In a similar way, the degree of precision of the treatment plan was determined, too, describing it as correct/incorrect. Statistical data processing and analysis of the obtained results were performed using the Diagnostic and Agreement Statistics (DAG) Software http://www.mhri.edu.au/biostats/DAG_Stat and software package SPSS for Windows version 16.

Agreement among the teleconsultants was obtained dividing the number of patients with the achieved agreement with the total number of examined patients. The following elements were determined: sensitivity (SE), specificity (SP), and efficacy (EFF). The degree of achieved agreement between teleconsultants using the method of teledentistry was expressed as the Cohen’s kappa (κ) coefficient. The kappa coefficient for the confidence interval of 95% was presented according to the Landis and Koch scale (Table 1). Statistical significance of the differences between correct and incorrect diagnoses, planned interventions (yes/no; extractions, incisions, hospitalizations, antibiotic therapy), precision, sensitivity, and specificity, and comparison of all the obtained values were done using the z-test, and testing for non-parametric characteristics was done using the McNemar’s χ²-test (contingency table 2 × 2) for the threshold of significance at $p = 0.05$.

![Fig. 1 – A newly received teleconsultation request in the XPA3 Online system.](image-url)

**Table 1**

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Results

Overall 414 patients were examined and 414 diagnoses were made. All the received photographs, x-rays, and other documents, were declared as usable by the teleconsultants. Out of 414 (100%) patients, teleconsultants stated that there was no dentogenous infection in 18–22 (4.35–5.31%) cases. They established that the most common area involved with dentogenous infection was the submandibular region, in 84–93 (20.29–22.46%) cases, followed by submental, in 63–69 (15.22–16.67%) cases, and buccal space, in 57–66 (13.77–15.94%) cases (Table 2). As the type of infection, teleconsultants identified abscess in 328–333 (79.23–80.43%) cases, while phlegmon was diagnoses in 47–51 (11.35–12.32%) cases (Table 2). Trismus was found in 31–34 (7.49–8.21%) cases (Table 2). Regarding treatment, the teleconsultants suggested 233–241 (56.28–58.21%) extractions, 159–187 (38.41–45.17%) incisions, hospital admission in 42–49 (10.14–11.84%) patients, and antibiotic treatment in 398–406 (96.14–98.07%) cases (Table 2). As the type of necessary incision, intraoral incision was recommended in 113–126 (67.66–67.38%) cases, and extraoral one in 50–60 (31.45–32.62%) cases (Table 2).

The highest degree of teleconsultant agreement as to the primary spaces involved with infection was achieved between TC1 and TC2 (κ = 0.827), and the lowest degree between TC6 and TC8 (κ = 0.879). Regarding differential diagnosis abscess/phlegmon, the highest degree of agreement existed between TC8 and TC9 (κ = 0.933), and the lowest degree between TC5 and TC10 (κ = 0.889). As for trismus, the best agreement existed between TC1, TC2, TC3, TC4, TC7, TC8, TC9, and TC10 (κ = 1.000), with the deviation with TC5 and TC6 (κ = 0.600).

The highest degree of diagnoses agreement of primary infection-involved spaces related to clinical examination was present in TC1 with 2 erroneous diagnoses (0.48%), and the lowest degree was found in TC3 and TC5 with 6 erroneous diagnoses (1.45%), for statistical processing of the results (Table 7 and Table 1), κ = 0.971, SE = 98.5%, SP = 98.5%, EFF = 98.5%, indicating almost a complete diagnostic agreement. As to the type of infection, the highest agreement with clinical examinations was found for TC1, with 2 erroneous diagnoses (0.48%), and the lowest agreement was observed for TC6, with 10 erroneous diagnoses (4.14%), for statistical processing of the results (Table 1), κ = 0.951, SE = 97.6%, SP = 97.6%, EFF = 97.6%, indicating almost complete diagnostic agreement. As for trismus, the highest degree of agreement with clinical examination was observed for TC1, TC2, TC3, TC4, TC7, TC8, TC9 and TC10, without any diagnostic errors, and the lowest for TC5 and TC6, with 1 error each (0.41%). Diagnostic differences were not statistically significant.

Regarding the suggested therapy (Table 2), the highest degree of agreement was observed between TC2 and TC10, as well as between TC4 and TC6 (κ = 0.919), the lowest degree between TC5 and TC7 (κ = 0.892), while the opinions were somewhat different regarding the choice of intra- or extraoral incision approach (Table 2).

Discussion

The purpose of this paper was to assess the possibility of using modern methods of teledentistry in the management of patients with dentogenous infections, and to answer to the questions: if we can make a clinically reliable diagnosis at a distance, and are we able to assess the primary treatment indicated in such cases (extraction of the causal tooth, incision, need for hospital admission, and antibiotic therapy).

Almost a completely achieved agreement in making the diagnosis of primary involved spaces (κ = 0.971) and that concerning the type of infection (κ = 0.951) and the presence of trismus (κ = 1.000 in 80% of TCs and κ = 0.600 in 20% of TCs), open the possibility of reliable distant patient management. The results showed that using the method of teledentistry we can make clinically acceptable diagnosis of dentogenous infections, and that the method can replace real time diagnostic evaluation, i.e. direct visual/tactile diagnostic approaches. Regarding the basic therapy assessment, almost a perfect agreement was achieved too (κ > or = 0.892), indicating the possibility of distant counselling as to the primary treatment approaches, with clear statements about the necessity of hospital admission of patients with dentogenous infections.

One of the striking advantages was the fact that 98% of teleconsultation requests were responded to in the requested time span (30 min to 6 h), which indicated that teledentistry consultation can be a valuable tool for saving the time to specialist examination. Patients were placed in the right management track in a short time, saving valuable time in cases of emergency, which can be of a decisive influence regarding the development and outcome of infection. The results confirmed that “store and forward” teledentistry system resolves the need of physicians for consultation in a cheap, effective, and rapid way, in this case in the pathology of dentogenous infections.

We have not encountered in the literature any studies dealing with the validation of teledentistry diagnosis and assessment of therapy for dentogenous infections, but there were studies which evaluated teledentistry agreements in the related fields. Thus Salazar-Fernandez et al. 10 in their large study of teledentistry consultations in the diseases of temporomandibular joint found that using the store and forward teledentistry method, the opinion of a specialized consultant can be obtained in an effective and efficacious way, suggesting that the method should have been more widely used by oral and maxillofacial surgeons. Herce et al. 11, suggested that using the store and forward teledentistry method the pathology of third molars could be effectively assessed within the pre-surgical treatment, avoiding thus numerous preliminary hospital visits by the patient. Duka et al. 12, comparing the diagnoses of third molar pathology using teledentistry and conventionally, found that the problems could be adequately evaluated by both approaches. Ignatius et al. 13, in their 13 months’ study of the possibility of distant diagnosis and distant planning of prosthetic solutions in patients requiring prosthetic or oral rehabilitation treatment, concluded that teledentistrations were successful in 24 out of 27 cases. Brüllmann et al. 14, in their study of recognition of...
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open dental root canals using telemedicine, found that dis-
tant consultation of experienced dentists can be of great help
to younger colleagues regarding the correct diagnosis of
dentist. Kopycka-Kedzierawski and Billings 15 found that using telemedicine the prevalence of caries in
could be successfully assessed, collecting the inform-
from children in the cohort group for 12–60 months
and using simultaneously the methods of telemedicine and
traditional visual/tactile examination. The results of the re-
spective authors agree with our own results, especially re-
garding the reliability of used teledentistry methods, with
special stress on the store and forward telemedicine method.

Since dentogenous infections represent a relatively
common pathology, our study offered a significant insight
into the excellent prospects of distant examination and treat-
ment planning in the management of these patients. In con-
trast, inadequate management and frequent antibiotic treat-
ments of dentogenous infections with only oral antibiotics
(which is rather common in the routine dentistry practice),
contribute to a rapid development and wide spread of these
infections, endangering thus the general health of our pa-
tients 16. In these patients, the first clinical examination is of
key importance, since it requires ample clinical knowledge
and experience 17. Using the methods of telemedicine, other
specialists or, later, even the patients themselves can seek
adequate expert help from oral and maxillofacial surgeons or
otrhinolaryngologists, i.e. from subspecialists in the ap-
propriate fields, getting the requested advice regarding proper
diagnosis or treatment. Timely teleconsultation can help
physicians in charge of the patients to react better, sup-
ported by sufficient expertise; in many cases, the spread of
infection into deeper regions of the neck can thus be pre-
vented (the origin of such infections is dental in over 40% of
cases, and lower molars are most commonly implicated in
that regard) 18.

As the precondition of proper telemedicine diagnosis,
adequate technical-technologic equipment is required for the
collection, analysis, and exchange of diagnostic data between
teleconsultants. We achieved excellent results using 3.1
megapixel or stronger cameras (with built in electronic flash
units). Since digital photographic equipment is becoming in-
creasingly cheaper, with imaging resolution being on the rise
too, we believe that the resolution of 3.1 megapixels con-
stitute the minimum for teledentistry imaging and that there is
no need to go below that standard. It is also necessary to ad-
here to the common procedure of taking intraoral or extraoral
photographs, capturing by digital photographs the real situa-
tion in the mouth, as well as extraoral changes 15. The patient
should be photographed en face and bilaterally, taking as
sufficient to reduce microorganism resistance, telemedicine con-

The results showed an almost complete agreement
between teleconsultants regarding the therapy (κ = 0.892),
there is the possibility of help to remote nonspe-
cialists in the decision-making whether to extract the causal
tooth at once, or to postpone the extraction and perform only
cision. This can have a marked impact on infection sub-
side and alleviation of pain, as well as on the general status of
the organism 20. Viewed from the aspect of general inten-
tion to reduce microorganism resistance, telemedicine con-
sultation in such patients offers an additional differentiation
regarding the decision to include antibiotic therapy or to
stick to tooth extraction only, providing surgical debride-
ment, removal of the infection cause, and drainage. In this
way, unnecessary increase of resistance to antibiotics can be
minimized 21. An almost complete agreement between the
teleconsultants was achieved also regarding the need for
hospital admission, eliminating the possibility of inadequate,
nonspecialist assessment of the need for constant medical
observation, i.e. that the present dentogenous infection had to
be seriously considered.

The method of telemedicine used in the study can im-
prove the quality of health care, facilitate the work of doc-
tors, reduce treatment costs, and contribute positively to the
budget of the health care system.

Conclusion

Our study showed that using the method of telemed-
cine it is possible to make correct clinical diagnosis of den-
togenous infections equally well as in real time, assess their
nature and course, and successfully consider the treatment
option.

Telemedicine consultation is a vital patient manage-
tool of key importance to any field doctors or those in
geographically remote regions, but also to any other doctors
who are not sufficiently specialized in the area of dentoge-
nous infections.

In addition to its being a valuable medical tool, the
method of telemedicine significantly contributes to cost-
effectiveness of health care and speeds us the process of
healing.

Acknowledgement

This paper is dedicated to the memory of Aleksandar
Janković MD, PhD, from Niš, Serbia.
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