Final report for 2021 Biomedical Research Award (Phimon Atsawasuwan)

Title of Project: Evaluation of Positivity Rate of COVID-19 in Orthodontic Practice

Award Type: Biomedical Research Award (BRA)

Period of AAOF Support: May 1, 2021 through June 30, 2023

Institution: University of Illinois, Chicago

Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s):

Phimon Atsawasuwan (Principal Investigator)/ Shrihari Kadkol, Veerasathpurush Allareddy, Sriram Ravindran (Co-investigator)

Amount of Funding: 30,000.00

Abstract

Aim 1: Evaluate the positivity rate of SARS-CoV-2 in the orthodontic patients compared to the positivity rate in the area.

The results from the collected saliva specimens from 1,437 orthodontic patients and the specimen was analyzed for the PCR-based assay to detect SARS-CoV-2 for surveillance purposes at the Pathology Laboratory, College of Medicine, UIC. We compared the positivity rate of COVID-19 infection in the orthodontic clinic at the University of Illinois Chicago and the ones of Chicago and Cook County, Illinois. We found 9 cases of SARS-CoV-2 infection in the orthodontic patient population. However, the correlation of positivity rate between the one in the orthodontic clinic, UIC and the one of Chicago or Cook County, IL was low. The correlation between the one of Chicago and the one of Cook County was high. We concluded that the risk of cross-infection from the patient to the orthodontic providers exists though at low rate.

Aim 2: Estimate the positivity rate of COVID-19 among orthodontists and staff in orthodontic practices.

The questionnaire study in the AAO member population demonstrated low response rate was low (2.9%). The preliminary results showed 69.2% reported seeing fewer patients, while 5.0% closed their practices permanently. All orthodontists increased the use of PPEs. 60% used teledentistry and 64.2% replaced impression with digital scanning. 5.8% of orthodontists and 54.2% of staff reported a history of COVID-19 infection. 95.7% of orthodontists and 94.0% of their staff were vaccinated.

Respond to the following questions:

Detailed results and inferences:*

If the work has been published, please attach a pdf of manuscript

Yes. Pdf files of publications are attached.

Were the original, specific aims of the proposal realized?*

Yes.

Were the results published?*

Yes. The information is provided below.

1. Durbin P., Viana G., Allareddy C., Kusnoto B., Ravindran S., Kadkol S., Atsawasuwan P. COVID-19 Infection Rates and Mitigation Strategies in Orthodontic Practices. BMC ORAL HEALTH 2023 Jan 7;23(1):8. doi: 10.1186/s12903-022-02705-1.
2. Atsawasuwan P., Martin Del Campo D., Martin Del Campo L., Viana G., Ravindran S., Allareddy V., Kadkol S. Positivity Rates of SAR-CoV-2 Infection in Orthodontic Patients at the Orthodontic Clinic, University of Illinois Chicago, PLoS ONE 2022 Jun 23;17(6):e0270311. doi: 10.1371/journal.pone.0270311.

Have the results of this proposal been presented?*

Yes. The information is provided below.

1. Atsawasuwan P., Martin Del Campo D., Martin Del Campo L., Bernab M., Ravindran S., Viana G, Allareddy V., Kadkol S. Frequency of SAR-CoV-2 Infection in Orthodontic Patients at the Orthodontic Clinic. University of Illinois Chicago. Annual Meeting of The Eastern Component of the Edward H. Angle Society of Orthodontists (EHASO), St. Peterburg, FL, USA, 2022. (oral presentation)
2. Viana, G, Lown, S, Ragab, O, Bernab, M, Atsawasuwan, P. Perception of Orthodontic Patients toward COVID-19 Transmission in the Orthodontic Clinic During Summer-Fall 2021. 123rd Annual Session-American Association of Orthodontists, e-poster#1162, Chicago, IL, April 2023. (e-poster presentation)
3. Atsawasuwan, P, Del Campo, D, Del Campo, L, Allareddy, V, Kadkol, S. COVID-19 Infection Rate in Orthodontic Patients at the University of Illinois Chicago. 122nd Annual Session-American Association of Orthodontists, e-poster#1474, Miami, FL, May 2022. (e-poster presentation)
4. Durbin P, Viana G, Kusnoto B, Allareddy V, Atsawasuwan P. COVID-19 Infection Rate and its Mitigation Strategies in Orthodontic Practices. 122nd Annual Session-American Association of Orthodontists, e-poster#1473, Miami, FL, May 2022. (e-poster presentation)
5. Durbin P, Viana G, Allareddy V, Kusnoto B, Ravindran S, Kadkol S, Atsawasuwan P. COVID-19 infection rate and its mitigation strategies in orthodontic practices. University of Illinois Chicago, College of Dentistry, Clinic and Research Day, ABSTRACT #9 PHS, 2022 (poster presentation).

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*

With the generous funding from AAOF, we have investigated the effect of COVID-19 in orthodontic practice and reported our findings as 2 publications in PLoS one and BMC Oral Health which are the peer-reviewed journal with high impact factor and presented our findings at local and international conferences as stated above. We acknowledged the funding from the AAOF in all presentations and publications. The valuable finding related to COVID-19 in orthodontic practice is impossible without the support from the AAOF. We hope that the report from our study will be crucial information for the potential mitigation strategies for the next pandemic event if occurred in the future. In addition, the publications from this study will be used to demonstrate as scholarly products from my promotion and tenure process.

Accounting: Were there any leftover funds?

We utilized all funds from the AAOF. There is no remaining fund.

The report was submitted on 6/12/2023

Due by 06/30/2023.

BMC Oral Health

RESEARCH

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COVID-19 infection rates and mitigation strategies in orthodontic practices

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Abstract

Background COVID-19 has impacted and increased risks for all populations, including orthodontic patients and providers. It also changes the practice management and infection control landscape in the practices. This study aimed to investigate the COVID-19 infection and vaccination status of orthodontic providers and mitigation approaches in orthodontic practices in the United States during 2021.

Methods A validated 50-question research electronic data capture (REDCap) browser-based questionnaire was distributed to 12,393 orthodontists and pediatric dentists who reported actively providing orthodontic treatment. Questions were designed to collect demographic data of respondents, evaluate the COVID-19 mitigation approaches, and evaluate the history of COVID-19 infection and vaccination status of the orthodontic providers. Associations of demographic and the COVID-19 mitigation approaches were assessed using chi-square tests at the significance level of 0.05.

Results Four hundred fifty-seven returned the survey (response rate 3.69%) for analysis. Most respondents were vaccinated, and increased infection control measures in response to the pandemic. Half of the respondents practiced teledentistry and switched to digital impression systems. Two-thirds reported difficulties in attaining PPEs due to the increased cost and scarcity of PPEs. About 6% of respondents reported a history of COVID-19 infection, and 68.9% of their staff had COVID-19 infection. Statistically significant associations were found between increased practice experience with difficulties in acquiring PPE ($p = .010$). There were no significant associations between races of respondents, geographic location, and years of practicing when cross-tabulated with vaccination status or COVID-19 infection rate ($p > .05$).

Conclusion Increased infection control strategies were employed in almost all orthodontic practices in addition to existing universal precaution. Most of the orthodontic providers and their staff members were vaccinated. While staff's infection rates were an issue, doctors' infection rates remained low.

Keywords Orthodontic providers, COVID-19, COVID-19 vaccine, Infection control

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Background

A novel coronavirus was discovered in Wuhan, China, at the end of 2019 [1]. In February 2020, the World Health Organization designated the virus as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes Coronavirus disease 2019 (COVID-19) [2]. The SARS-CoV-2 virus is mainly transmitted through exposure to infectious respiratory fluids, especially the

inhaling very fine respiratory droplets and aerosols [3] and can occur in asymptomatic, presymptomatic, and symptomatic stages of infection [4]. This nature of transmission puts dental healthcare providers at increased risk of infection, as orthodontic providers regularly perform aerosol-producing procedures [5]. The most significant risk of transmission via inhalation is within three to six feet of an infectious source [3] while another mean of possible in-office transmission is touching oral/nasal mucous membranes with hands contaminated with exhaled respiratory fluids or contaminated surfaces [3, 6]. With the spread of new variants, there is concern that symptoms may worsen as the virus mutates and lead to the next surge of a pandemic [7]. COVID-19 vaccines have been shown as one approach to control the development of virus mutation and to contraction of COVID-19 effectively and significantly reducing severe disease, hospitalization, and death [8]. The Centers for Disease Control and Prevention (CDC) has launched the guidelines to implement COVID-19 mitigation for dental procedures to prevent in-office transmission [9]. A study gauging COVID-19 positivity rates in dental hygienists in the United States found that 3.1% had tested positive or been diagnosed with COVID-19 [10], while the rate in general dentists was found to be lower (0.91%) [11] with 2.6% in a 6-month longitudinal follow-up study [12]. COVID-19 also affected the mental health of dental healthcare workers as fluctuated anxiety and depression [13, 14]. Few studies reported the positivity rates of patients seeking dental treatments including emergency, pediatric and orthodontic treatments ranging from 0.027 to 6.7% [15–19]. Due to its high transmitted nature, COVID-19 leads to the report of 99.7% of dentists enhancing PPE protocols to mitigate the COVID-19 transmission [11]. An online questionnaire study in orthodontists to investigate the source of information for COVID-19 in 2020 demonstrated that their most accessed information sources were professional association websites (>70%) and online news sources (61%) which the state or local dental associations (53%) and the American Association of Orthodontists (50%) were reported as the most valuable sources of information [20]. Though the guidelines to mitigate COVID-19 transmission in dental practices exist, there are no reports on how the actual approaches were implemented especially certain groups such as orthodontic providers, which the nature of their practices was different from other types of dental practices.

Methods

This study aimed to investigate orthodontic providers' COVID-19 infection and vaccination rates and mitigation approaches in orthodontic practices in the United States in 2021.

Participants

The voluntary survey was disseminated to 4,414 active members of the American Association of Orthodontists (AAO) and all 7,887 active members of the American Academy of Pediatric Dentistry (AAPD), and all 92 members of the Angle Midwest Society. The survey was performed from January 1st, 2021 to December 31st, 2021. To maximize the resulting number of respondents no sampling scheme was adopted. Due to the descriptive nature of the survey, no formal prospective sample size calculations applicable to hypotheses testing or error rates were attempted. We distributed the questionnaires to all members of the American Association of Orthodontists and the American Academy of Pediatric Dentistry and used the inclusion and exclusion criteria to determine the sample numbers for the data analysis.

Ethical consideration

This survey study was granted exemption from the University of Illinois Chicago Institutional Review Board (#2020 – 1469). All participants joined the study voluntarily and anonymously and the informed consent was stated when the participants logged in for the questionnaires.

Questionnaire design

The questionnaires were generated using REDCap (Research Electronic Data Capture) platform. A draft questionnaire was developed and validated with a panel of 40 experienced orthodontists to evaluate the questions and provide input regarding the validity, length, sequence, and relevance of the questions. The questions were distributed to 40 orthodontists in private practices and academic institutes to evaluate the validity of the questions and feedback. These processes were conducted to establish the solid structure of the content and face validity of the questions and to ensure the answers render the understanding of the COVID-19 mitigation approaches and the nature of infection rate and vaccination rates in the orthodontic providers. The questions were modified according to the expert panel's feedback and the fluidity of federal COVID-19 restrictions. The final 50-item question survey consisted of yes/no options, dropdown choices, multiple-choice, and open-ended formatted answers. The questionnaire was subdivided into three sections: (1) demographic information (8 questions), (2) in-office COVID-19 mitigation approaches (32 questions), (3) history of COVID-19 infection and COVID-19 vaccination, and attitudes of the orthodontic providers (10 questions). The quick response (QR) code was generated to link the questionnaire (Fig. 1)

Fig. 1 QR code linked to the set of questionnaires. The QR code was distributed to the participant via electronic mail

Statistical analysis

Descriptive statistics analysis by frequencies (%) were performed for each of the survey questions along with selected cross tabulations. When applicable, Chi-square statistics for associations were assessed. Statistical significance was set at $\alpha = 0.05$ level. The data was analyzed using IBM SPSS Statistics for Windows, version 28.0.

Results

Participants

This cross-sectional design study was disseminated to 12,393 practitioners, and 457 returned responses (response rate 3.69%) from January 1st, 2021 to December 31st, 2021. We observe that with the resulting sample size we can estimate all proportions to within 6% points with a confidence level of at least 95%. Of those responses, 154 were from pediatric dentists who did not provide orthodontic treatment and the data from this group were excluded from the analysis. About 66.3% of respondents were identified as males and 33.7% as females. About 82.8% of respondents were white/Caucasian, with the second-largest population being Asian (9.7%). About 91.0% of respondents were ethnically non-Hispanic (Fig. 2). The primary group of respondents was aged 50–59 (28.5%) and followed by the group of age 60–69 (25.5%) (Fig. 2). Over 50% of respondents have been practicing for at least 21 years. About 46.4% of respondents were identified as solo practitioners, while 30.3% responded that he or she was in a group practice setting. 7.5% were associated, 7.5% worked in a corporate office, 4.9% were hospital-based, and 9.0% were university-based. 2.6% of respondents listed "other" practice types, including military service and working at federally qualified health centers (FQHCs), as shown in Fig. 3. The respondents were distributed into geographical regions by AAO constituencies using their zip codes. The largest group of respondents was located in the states represented by the Midwest Society of Orthodontists (85 responses, 31.8%). The second-highest respondent group was located in the Southern Society of Orthodontists states (44 responses, 16.5%), as displayed in Table 1.

Landscape of orthodontic practice management

According to the respondents, if they offered teledentistry to their patients after the pandemic, 138 respondents reported "yes" (51.7%), and the same number of respondents switched to digital impressions instead of alginate impressions to prevent the spread of COVID-19 (Fig. 4). Regarding practice-hour changes in response to the COVID-19 pandemic, 57.7% reported seeing fewer patients, while 12.0% reported decreased working hours and 13.5% reported increasing working hours. Six respondents (2.2%) closed their practices permanently (Fig. 4). The most noticeable group that reported seeing fewer patients was in the > 30 years practicing group, in which 59 out of 84 respondents (70.2%) reported seeing fewer patients.

Infection controls

According to the respondents, the most common sources of information regarding COVID-19 infection control were the American Dental Association (80.9%), the US Centers for Disease Control and Prevention (CDC) (74.2%), State Dental Association (58.1%), and American Association of Orthodontists (AAO) (49.4%). Respondents were able to select more than one option. A frequency summary of information sources used is displayed in Table 2. Almost all practitioners reported disinfecting commonly touched surfaces and equipment in operatories between patients and offered staff facemasks. Most respondents required social distancing in the treatment area (206, 77.2%) and air purifiers or other filtration systems (180, 67.4%). Other patient pretreatment screening for infection control efforts included having patients fill out an exposure risk questionnaire (193, 72.3%), checking temperatures of both patients and self/staff (189, 70.8% and 170, 63.7%), and having parents or guardians wait outside the practice during the appointment (134, 50.2%). A complete summary of infection control results is included in Table 3. Regarding any struggles to attain PPE for their offices, 167 respondents (62.5%) reported "yes". About 115 (43.1%) cited increased costs of PPE, 166 (62.2%) cited limited supplies, 69 (25.8%) described the lower quality of PPE products. There were no statistically significant associations between geographic location and difficulty acquiring PPE, indicating that providers had difficulty acquiring PPE nationwide. However, there was a statistical significance of the association between the experience and reporting difficulties acquiring PPE

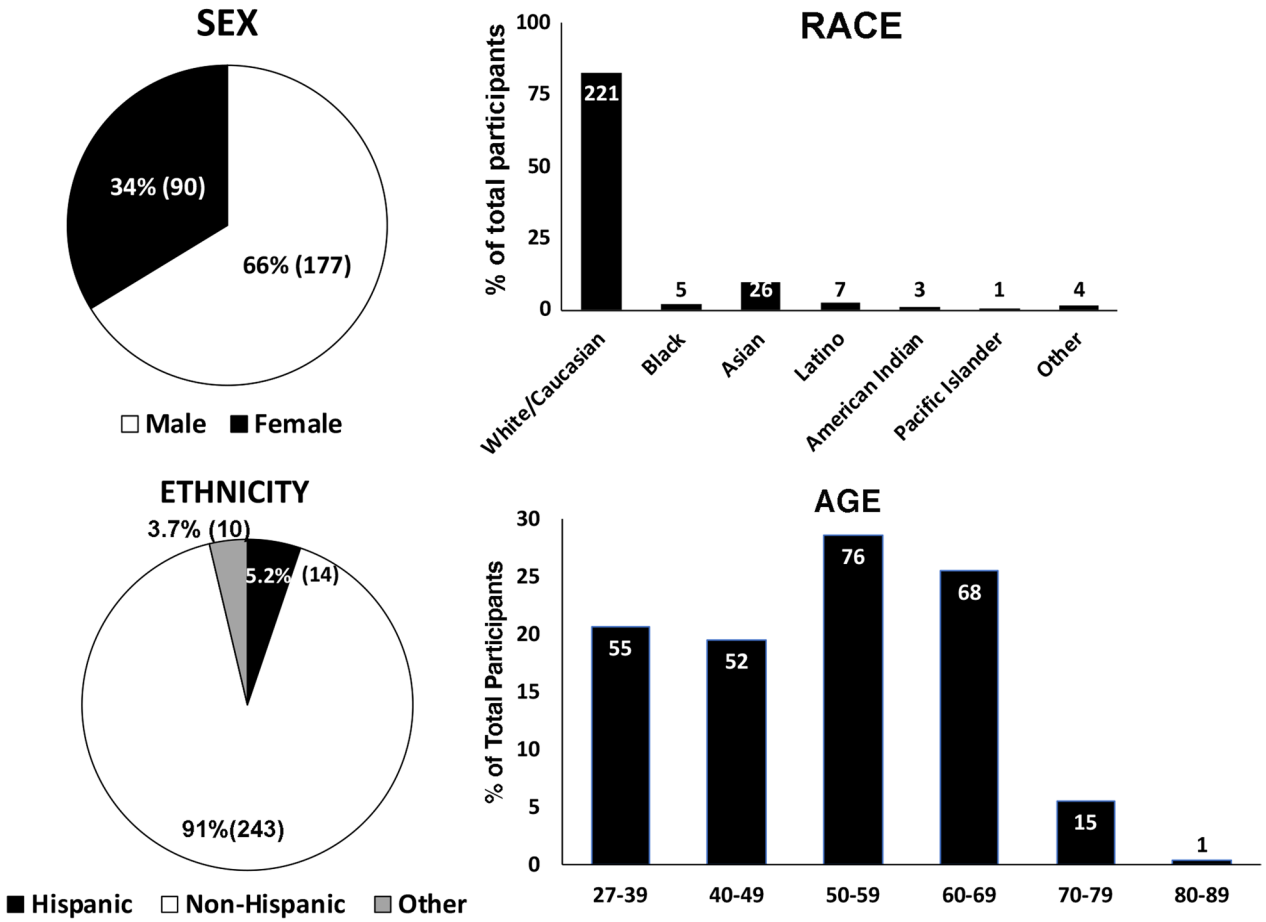

Fig. 2 Biological demographic profiles of the participants. The demographic profile represents orthodontic providers in all geographical areas in the United States

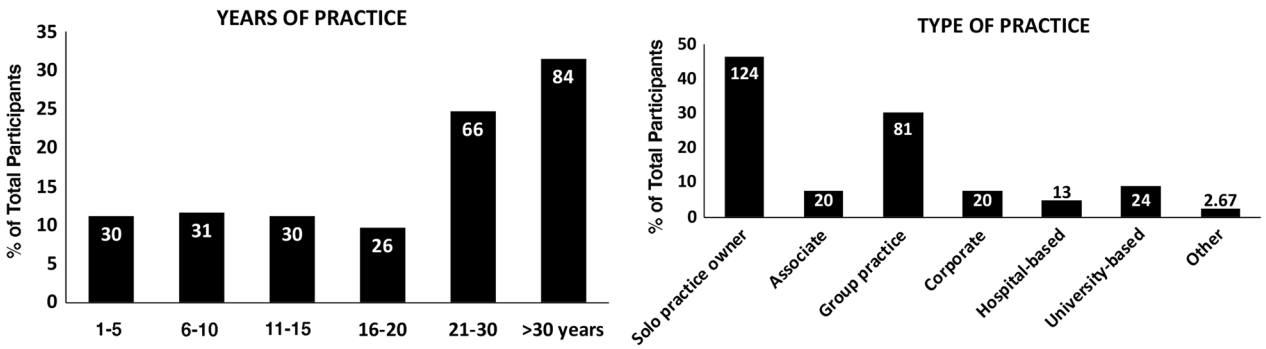

Fig. 3 Practice demographic profiles of the participants. The demographic profile represents orthodontic practice locations in all geographical areas in the United States

(Chi-square value = 15.133, p = .010). As practice experience increased, more respondents reported PPE acquisition difficulties.

Covid-19 infection and transmission

Regarding the history of COVID-19 infection of the providers and their staff members, 16 doctors (6.0%) responded "yes". One practitioner (6.3%) speculated a staff as the origin of transmission, one practitioner (6.3%)

Table 1 Geographic distribution of respondents

Society of orthodontists	Percent (%)
Midwestern	31.8
Southwestern	8.2
Southern	16.5
Pacific Southwest	11.6
Middle Atlantic	7.9
Northeastern	10.9
Great Lakes	9.7
Rocky Mountain	3.4
Total	100

speculated a patient, and 14 practitioners (87.5%) speculated sources from outside the office. Regarding the history of COVID-19 of the staff members, 184 (68.9%) responded "yes", with 17.4% respondents having one staff member test positive, 23.4% having two staff members test positive, 19.0% having three staff members test positive, and 40.2% having more than three staff members test positive. Regarding transmission sources, 2.7% reported possible in-office transmission, 1.1% reported possible transmission from patients, and 96.2% reported possible transmission from sources outside their practices. 256 out of 267 respondents provided their staff with workplace guidelines for COVID-19 transmission and exposure prevention.

COVID-19 vaccination status

Regarding COVID-19 vaccination status, 94.0% replied "yes", Twelve practitioners (4.5%) responded "no" to receiving the vaccine and the remaining did not state in the response. The reason for the COVID-19 vaccine hesitancy in the providers is summarized in Table 4. Regarding the COVID-19 vaccination status in their staff, 249 respondents (93.3%) reported that their staff had received

Table 2 Reported source of information regarding COVID-19 (responders could choose more than one)

Source of information	Percent (%)
American dental association (ADA)	80.8
American association of orthodontists (AAO)	49.4
American academy of pediatric dentistry (AAPD)	29.2
Occupation safety and health administration (OSHA)	43.8
Organization for safety and aseptic procedures (OSAP)	2.6
State dental association	43.0
Local health department	32.9
Centers for disease control and prevention (CDC)	74.1
World health organization (WHO)	9.7
Dental school website	6.3
Other	5.2

Table 3 Reported infection control measures

Infection control effort	Percent (%)
High-powered Suction Modification (i.e., Isolite or Dryshield)	26.2
Extraoral high-power suction	31.1
Installed physical barriers (between units)	40.1
Installed physical barriers (between patients and doctors)	7.5
UV light systems	19.5
Air purifiers or other filter systems	67.4
Negative pressure room	7.1
Exposure risk questionnaire	72.3
Pre-visit screening (1–2 days prior)	53.2
Temperature check (patient)	70.8
Temperature check (self/staff)	63.7
Pre-treatment rinse	39.0
Disinfect frequently touched surfaces	99.6
Social distancing (treatment area)	77.2
Patients waiting outside the practice	50.2
Parent/guardian allowed in treatment area	69.3
Disinfect all equipment in operatory	98.9
Provide facemasks (staff)	99.6
Provide facemasks (patients)	70.8

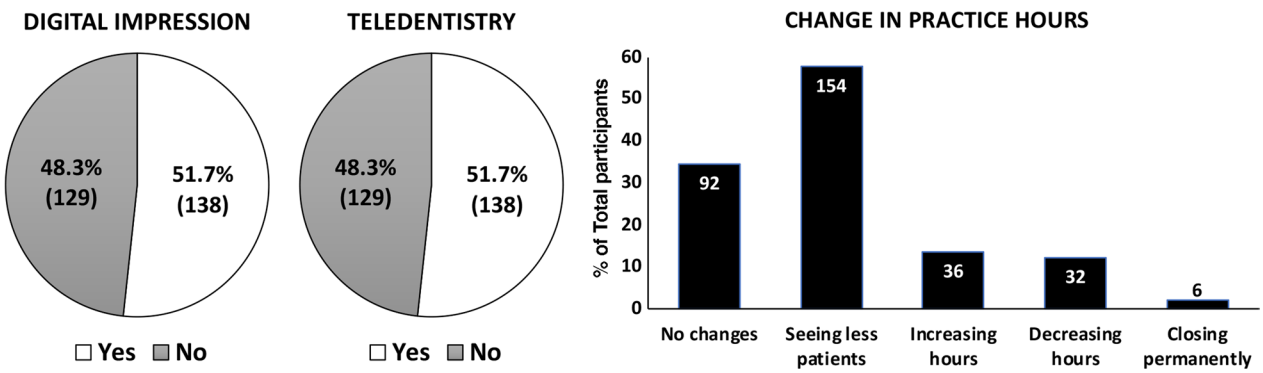

Fig. 4 Changes of clinical practice management due to COVID-19 pandemic. The representatives of changes in contemporary orthodontic practice affected by the COVID-19 pandemic

Table 4 Orthodontic providers' reasons for not receiving COVID-19 Vaccine ($n = 12$)

Reasons for Not Receiving Vaccine	Frequency	Percent (%)
Lack of access	1	6.7
Lack of trust	7	46.7
Previously infected with COVID-19	2	13.3
Mitigation measures are sufficient protection	4	33.3
Medical exemption	2	13.3
Religious exemption	0	0
Other	2	13.3

they would educate the staff member on the safety of the vaccine, 31.1% would refer the staff member to their primary care physician, 13.5% would use peer pressure, 23.2% would do nothing, and 13.1% stated other reasons.

Association between demographic data and COVID-19 infection control and infection

Crosstabulation statistical analyses were performed to evaluate the associations between the respondents' age and various parameters tested in our survey. There were no statistically significant associations between the respondents' age, vaccination rate, and COVID-19 infection rate. This lack of statistical significance could be attributed to overall high vaccination rates (94.0% for doctors), lower COVID-19 infection rate (6.0%), and an overall willingness to encourage vaccination (70.8%). Crosstabulation statistical analyses were tested to evaluate the associations between the geographic location of practices and various questions. No significant associations were found in changes in practice hours, vaccination rate, difficulty in acquiring PPE, COVID infection, and willingness to encourage staff to receive the vaccine. The lack of association between vaccination rate and vaccine encouragement could be due to overall high vaccination rates and willingness to encourage vaccination. When analyzing the COVID-19 infection rate, no association could be attributed to our samples' relatively low infection rate (16 out of 267 respondents, 6.0%).

Discussion

This comprehensive study aimed to evaluate COVID-19 infection rates and mitigation strategies to prevent the transmission of COVID-19 in orthodontic provider-specific settings. The participants' demographic profiles in this study represent 84.8% private practitioners with broad geographical locations and as practice owners who represented the actual orthodontic practitioners in the United States. The overall infection rate in this study was 6.0%, which is higher than a similar longitudinal study in the general dentist population (2.6%) and the general population (1.1%) [12]. The range of response for survey research in the literature is 33–44%; however, the response rate could be varied depending on the topics, incentives and targets of participants [21, 22]. In addition, online surveys yielded an average 12% lower response rate than other modes of surveys[23]. We speculate that our low rate of participation was due to no incentives for participation and the length of questionnaires. However, the validated and comprehensive set of questionnaire in this study provides information of practice management and evidence for the orthodontic practices for the preparation of orthodontic practice for the future pandemic event. A recent report showed the positivity rate in orthodontic patients was 0.626% and a potential risk of COVID-19 transmission from patients to orthodontic providers remains, even with asymptomatic and vaccinated patients [15]. Our survey respondents cited the ADA website (80.9%), CDC website (74.2%), and state dental association websites (58.1%) as the most commonly used sources for COVID-19 information. These results are similar to a previous study in an orthodontic population, which found that 73% of respondents cited professional association websites as the most commonly accessed sources [20]. More use of social media news sources was reported in the previous study [20]. Questions 9–40 gauged practitioners' mitigation approaches with similar questions in a previous study of general dentists [12]. Regarding wearing masks/eye protection, our results were consistent with a similar study of general dentists. 85.4% responded that they were wearing goggles or glasses, similar to the 81.8% of general dentists who reported always wearing masks and eye protection, regardless of the procedure [12]. As practice experience increased, more respondents reported PPE acquisition difficulties. This finding could be attributed to the observation that more experienced respondents often reported solo practice ownership, leaving the burden of acquiring PPE on them. In contrast, the less experienced respondents may work as associates who are not responsible for acquiring the PPEs. Disinfection of frequently touched surfaces was reported in 99.6% of our respondents (266 out of 267), similar to results found in a general dentist population (99.7%) [12]. However, our results showed lower percentages of orthodontists providing temperature screening, physical protection in the office, pre-appointment screenings, and encouraging social distancing. These results ranged from 40.1 to 77.2%, depending on the type of infection control measure. A similar study in a general dentist population showed that these measures were employed by greater than 95% of general dentists [12]. A study suggested simple screening methods are not sufficient and point-of-care (POC)

testing may be implemented in dental offices [24]; however, the cost of unit and specificity and sensitivity of the tests are still controversial for routine application[25, 26].

Our results are similar to those found in a general dentist population regarding enhanced mask use; 111 out of 267 (41.6%) of respondents confirmed they were wearing an N95 respirator, while 127 out of 267 (47.6%) reported wearing a KN95. In a general dentist population, an average of 59% of respondents replied that they wore an N95 or equivalent during some procedures [12]. This study showed that most respondents used face shields and goggles or glasses (67.8% and 85.4%, respectively). These infection control measures can help mitigate the spread of COVID-19 through the prevention of eye exposure [27]. Overall, our respondents appear to be taking the necessary steps to mitigate the spread of COVID-19 in their offices through stringent disinfection and proper PPE use. Increasing the use of intraoral suction devices and pretreatment rinses should be encouraged as adjunctive steps to lower the transmission risk of COVID-19 and similar pathogens [28].

Overall, the 6% infection rate was significantly lower than that found in a similar study of frontline healthcare providers, which showed a prevalence rate of 29% [29]. This lower positivity rate in an orthodontic population could be attributed to the increased use of proper PPE throughout the pandemic as the standard infection control in dental practices to prevent SARS-CoV-2 transmission [28]. Most respondents attributed their infection sources to outside the office (87.5%). This result would also support the conclusion from the studies reporting that proper PPE in an office setting limits the transmission of COVID-19 even in a relatively high-risk setting, as the providers may not be as stringent in their PPE use outside of the office [28, 30]. The overall vaccination rate for the orthodontic providers in our study was 94.0% which was significantly higher than the rate in the general population (63.8% as of January 31st, 2022) [31]. This vaccination rate is similar to one published according to the ADA Health Policy Institute, which reported 89.8% of dentists were fully vaccinated (as of June 2021) [32] and is also significantly higher than the vaccination rate in healthcare providers (70.0% as of September 15th, 2021) [33]. A higher vaccination rate in dentists compared to other healthcare workers could be attributed to the fact that all dental procedures require the removal of a facemask with the increased risk of COVID-19 transmission. In United Kingdom, 21% of orthodontic providers were not confident about the potential beneficial effects of a vaccination programme on orthodontic clinical service provision [34]. Geographically, there was no significant difference between constituencies in the overall vaccination rate. There were reports of COVID-19 hesitancy among dentists, dental hygienists, and dental students [35–37]. However, in the orthodontic provider population in this study, the rate of vaccination in this population is relatively high. This finding is most likely attributed to a high vaccination rate in dental providers, regardless of geographic location.

Limitations

This study has several limitations. First, the emergence of variants of SARS-CoV-2 at different duration during pandemic drove the changes in the transmission rate of COVID-19 in the population. Second, the COVID-19 infection control policy was consistently changed with the emergence of SARS-CoV-2 variants. Each SARS-CoV-2 variant possessed its transmissibility and severity of the symptoms. The infection control and patient screening approaches changed and overlapped with the announcement of the professional organization and central government policy. Third, the nature of response rate for the online questionnaire study is low; however the completeness and the cost-effectiveness of online format was higher compared to paper and pencil format. Though we sent two-time reminding emails to all participants and encouragement of confidentiality for participation, the response rate was not increased. The survey was performed as online and anonymous format to minimize desirability bias even though the participants' bias may exist during the survey since most of orthodontic providers may have practice universal precaution to prevent cross-contamination.

Conclusion

High percentage of orthodontic providers increased COVID-19 mitigation strategies to prevent in-office transmission and vaccinated against COVID-19. Low infection rates of COVID-19 in the orthodontic providers implicated that the implemented infection control measures successfully limited COVID-19 transmission in orthodontic practices.

Abbreviations

COVID-19	Coronavirus disease 2019
REDCap	Research electronic data capture
SARS-CoV-2	Severe acute respiratory syndrome Coronavirus 2
CDC	Centers for disease control and prevention
PPE	Personal protective equipment
AAO	American association of orthodontists
AAPD	American academy of pediatric dentistry
ADA	American dental association
QR	Quick response
POC	Point of care
N95	Standard for United States system for mask or respirator
KN95	Standard for Chinese system for mask or respirator

Acknowledgements
Not applicable.

Author contributions
PD collected the data and organized the data, GV analyzed and interpreted the data. VA, BK, SR, SK designed the experiment and provided resources, and PA was a major contributor in writing the manuscript and supervised the implementation of the study. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This survey study was granted exemption from the University of Illinois Chicago Institutional Review Board (#2020 — 1469). All participants joined the study voluntarily and the informed consent was stated when the participants logged in for the questionnaires. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Publisher's Note

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RESEARCH ARTICLE

Positivity rates of SAR-CoV-2 infection in orthodontic patients at the orthodontic clinic, University of Illinois Chicago

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Abstract

COVID-19 has impacted and increased risks for healthcare providers, including orthodontists. There is no information regarding the potential transmission risks in the orthodontic community. This study aims to compare the positivity rate of SARS-CoV-2 infection in orthodontic patients at the University of Illinois Chicago (UIC) orthodontic clinic to the positivity rate of the local population in Chicago. All orthodontic patients who sought treatment at the UIC orthodontic clinic from June 16 to October 31, 2021, were invited to participate in the study. Three milliliters of saliva from the participants were collected in the sample collection tubes and subjected to a polymerase chain reaction (PCR) based assay to detect SARS-CoV-2. All participants' age, sex, history of COVID-19 infection, and vaccination status were recorded. The COVID-19 positivity rates of Chicago, Cook County of Illinois, and the orthodontic clinic at UIC were compared. One thousand four hundred and thirty-seven orthodontic patients aged 6 to 70 years old (41.8% males and 58.2% females) participated in the study. Among all participants, nine participants tested positive for SARS-CoV-2 (5 males and 4 females). During the study, the average COVID-19 positivity rate at the UIC orthodontic clinic was 0.626%. All of the positive participants were asymptomatic, and two of the participants had a history of COVID-19 infection. Among all positive participants, three participants had received complete COVID-19 vaccination. An increased frequency of positive cases at the orthodontic clinic was observed during the time of high positivity rate in Chicago and Cook County. A potential risk of COVID-19 transmission from patients to orthodontic providers remains, even with asymptomatic and vaccinated patients.

Introduction

As of May 20, 2022, 82,820,565 cases of COVID-19, including 998,512 deaths, have been reported in the United States [1]. Transmission of COVID-19 can occur during symptomatic, presymptomatic, and asymptomatic periods. The asymptomatic/presymptomatic transmission

Competing interests: The authors have declared that no competing interests exist.

of COVID-19 makes the disease highly transmissible, and it is challenging to prevent its transmission [2]. In orthodontic practices, most patients are children and adolescents. Reports showed that children or adolescents frequently exhibited no symptoms despite being infected with SARS-CoV-2 [3–5]. In addition, SARS-CoV-2 viral loads are similar to adults when they have symptoms related to COVID-19 at early stages [6–8]. As such, there is a potential risk of SARS-CoV-2 transmission from patients to orthodontic providers in orthodontic practices. Currently, there is no report or information on the positivity rate of SARS-CoV-2 infection in the orthodontic patient population. Knowing the positivity rate may help initiate proper measures to mitigate the risk of transmission to orthodontic providers.

SARS-CoV-2 is the seventh member of the enveloped, positive-stranded RNA viruses [9]. SARS-CoV-2 can also be detected in saliva [10–12]. The reported salivary SARS-CoV-2 load ranged 10^2–10^6 copies/ mL [13,14]. Viral loads in saliva may also be higher than in nasopharyngeal (NP) or oropharyngeal (OP) swabs, increasing the risk of transmission by salivary droplets during coughing, sneezing, or even talking [10–12]. There are 3 approaches to test for SARS-CoV-2; (a) RT-PCR-based tests to detect viral nucleic acid, (b) rapid antigen tests to detect viral proteins, and (c) antibody tests to assess the body's immune response [15]. Reverse transcription-polymerase chain reaction (RT-PCR) is the gold standard of COVID-19 testing. Besides the NP or OP specimens, the US FDA issued an emergency use authorization (EUA) for saliva as specimens for COVID-19 diagnosis [16–18]. RT-PCR tests are highly sensitive and specific to detecting SARS-CoV-2, with most tests performed on NP/OP swabs [19]. Alternative molecular methods to detect viral nucleic acids, such as RT-LAMP and transcription-mediated amplification, have been reported [20–23].

SARS-CoV-2 can be detected with high sensitivity and specificity in saliva [10–12,16,17,24]. As a specimen type, saliva has many advantages over NP/OP swabs to detect SARS-CoV-2. Saliva can be self-collected, is non-invasive, and does not need a medium to transport to the laboratory [25]. In contrast, collecting NP/OP swabs requires trained personnel, swabs and viral transmitting media [26]. Being non-invasive, saliva can also be obtained multiple times for testing [25]. In addition, the self-collection of saliva reduces the risk of COVID-19 exposure to healthcare personnel during collection [27]. The sensitivity of SARS-CoV-2 detection in the saliva is comparable to that of NP/OP swabs [18,26]. Several studies have shown that SARS-CoV-2 can be detected in the saliva of asymptomatic persons and outpatients [16,17,28]. In May 2020, the US FDA issued an emergency use authorization (EUA) for tests to detect SARS-CoV-2 in saliva [29]. In Aug 2020, the molecular pathology laboratory in the department of pathology at the University of Illinois Chicago, a CLIA/CAP-accredited laboratory, developed and validated a one-step RT-qPCR test to detect SARS-CoV-2 in saliva. The lab-developed test was used to determine SARS-CoV-2 status in patients enrolled in this study. The test detects the S gene of SARS-CoV-2 with RNaseP as an internal control. The test is highly sensitive and specific and will detect all SARS-CoV-2 variants being monitored, variants of interest, and variants of concern as designated by the Centers for Disease Control and Prevention (CDC). The objective of the study was to evaluate SARS-CoV-2 positivity in the orthodontic patients visiting the orthodontic clinic at the University of Illinois Chicago using the test developed by the molecular pathology laboratory. Knowing the positivity rate of SARS-CoV-2 positivity may better help to assess the risk of SARS-CoV-2 transmission in the orthodontic clinic.

Materials and methods

Human subjects and saliva collection

All orthodontic patients who sought orthodontic treatment at the University of Illinois Chicago (UIC) at the orthodontic clinic from June 16 to October 31, 2021, were invited to

participate in the study. The study was approved by the Institutional Review Board of the University of Illinois (IRB# 2020–1465). The inclusion criteria included participants aged 7–50 years old who visited the orthodontic clinic for treatment. The participants did not exhibit any COVID-19 symptoms and reported no contact with any COVID-19 patients. The consent form was reviewed and obtained from the eligible participants and their parents/guardians, and the assent form. After initial screening with temperature checking, a set of questionnaires was used to evaluate the demographic information: age, sex, race, COVID-19 vaccination status, and COVID-19 infection history of the patients before the saliva collection. The participants were refrained from eating or drinking 30 mins before the saliva collection and instructed to spit their saliva (5 ml volume) in 50 ml Falcon® tubes with the sample de-identification label, placed in a biohazard bag, and dropped into a storage container. The specimens were transported on the same day for the PCR-based test [30] to the Molecular Pathology laboratory for testing. The results were reported within 24–48 hours. Due to the surveillance purpose, the testing was performed on de-identified specimens, and thus, results are not linked to individual subject. The surveillance testing results cannot be used for individual decision-making or treatment [31]. The COVID-19 positivity rates of Chicago, Cook County, and the orthodontic clinic at UIC were compared on a daily basis during the period of the study.

SARS-CoV-2 RT-qPCR test

Approximately 200ul of the saliva was extracted on the Kingfisher Flex instrument (Thermofisher) with MagMax Viral/Pathogen isolation kit reagents according to the manufacturer's protocol. Nucleic acids were eluted in a final volume of 60 μl. 5μl of the extract was analyzed in a one-step RT-qPCR reaction using primers and probes that amplify the S gene of SARS-CoV-2 and the cellular RNaseP gene. RNaseP served as an internal control to ensure adequate specimen collection, nucleic acid extraction, and the absence of RT-PCR inhibition. The primer and probe sequences were (5'>3"): Sgene-F2 AACTCAATTACCCCCTGCATAC, Sgene-R2 TAGTACCATTGGTCCCAGAGACA, Sgene Probe2 HEX TCAGATCCTCAGTTTTACATTC AACTCAGGACTTG BHQ1, RNaseP-F AGATTTGGACCTGCGAGCG, RNaseP-R GAGCG GCTGTCTCCACAAGT, RNaseP probe FAM TTCTGACCTGAAGGCTCTGCGCG BHQ1. Each 25μl reaction contained 6.25μl of 4X TaqPath 1-Step RT-qPCR mix, CG (Thermofisher), 10pmols of Sgene-F2 and R2 primers, 5 pmoles of Sgene Probe2, 0.5pmols of RNaseP-F and R primers and 0.5pmols of RNaseP probe. RT-qPCR was performed in Quantstudio 7 Flex real-time PCR machine (Thermofisher) in 96-well plates using the following program: 50° 30 mins (RT), 95° for 3 mins followed by 45 cycles of 95° for 10 secs and 56° for 30 secs. HEX and FAM signals were acquired in the 56° step. After completion, the data were analyzed by setting the thresholds to 0.1 for Sgene and 0.2 for RNaseP amplification curves, respectively. Any sample with an amplification curve for the Sgene that crossed the threshold was called "Detected". If the Sgene did not amplify and the RNaseP amplified with a Ct value of < 32, the sample was called "Not detected". If the Sgene did not amplify and the RNaseP also failed to amplify or if the RNaseP Ct value was >32, the sample was called "Invalid". Protocols to prevent contamination were followed throughout the workflow. Positive and negative controls were included in each run. The analytical sensitivity of the assay is 480 copies/ml of SARS-CoV-2 (95% detection frequency). The assay amplifies only the Sgene of SARS-CoV-2. The specificity of amplification was determined by spiking other respiratory viruses into saliva and by sequencing specimens with positive results. The positivity rate of SARS-CoV-2 amongst the patients in the orthodontic clinic was compared to the rate of positivity of the Chicago and Cook County databases on a daily basis.

Positivity rate of SARS-CoV-2 infection of Chicago and Cook County, Illinois

The positivity rates of COVID-19 in Chicago and Cook County, Illinois, were reported on the webpage of Chicago: COVID-19 dashboard https://www.chicago.gov/city/en/sites/covid-19/home/covid-dashboard.html and Cook County COVID-19 Surveillance Data webpage https://ccdphcd.shinyapps.io/covid19/. The data were updated daily, and the positivity rate of SARS--CoV-2 at the orthodontic clinic, the University of Illinois Chicago was calculated from the percentage of the number of positive cases from the total number of the tests on a specific day.

Statistical analysis

The positivity rates were reported as the percentage of the positive cases out of the total tested cases. To investigate positivity rate association among Cook County, Chicago and UIC, based on the sample activity from June, 14 to October, 29, 2021, a time-series graph and their respective cross-correlation coefficients were calculated using the software IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp.

Results

Demographic profiles were similar between UIC and the local community

One thousand four hundred and thirty-seven orthodontic patients ranged from 6–70 years old, with 41.8% males and 58.2% females (Table 1) participating in the study from June 16 to October 31, 2021. The distribution of ages of participants is shown in Fig 1, as 65% of the participants were aged from 12–25 years old. The comparison of the population by race between the patient at the UIC orthodontic clinic and Chicago is shown in Fig 2. None of the participants showed any symptoms related to COVID-19 and had no history of being in contact with COVID-19 patients. The participants and guardians completed the questionnaires related to the history of COVID-19 infection and vaccination. Among all participants, 17% reported a history of COVID-19 infection (Fig 3A), and about 10.7% out of 17% were aged between 12–25 years old (Fig 3B). Among all participants, 61.9% received complete doses of COVID-19 vaccination (Fig 4A), and approximately 40% were age group between 12–25 years old (Fig 4B). Among all participants, SARS-CoV-2 was detected in nine participants (4 females and 5 males, aged 10–44 years old). All of the positive participants were asymptomatic, and two of the participants had a history of COVID-19 infection. Three positive participants had received complete COVID-19 vaccination (Table 2).

There was no correlation between the positivity rates of COVID-19 infection at the orthodontic clinic and the ones of the local community

The average positivity rate of SARS-CoV-2 infection during the study was 0.626%. There was no correlation between the positivity of COVID-19 infection at the orthodontic clinic and the one of Chicago and Cook County, IL. The r^2 indicates approximately 89% of the positivity rate variability in Cook County and Chicago. The cross-correlation between the positivity rates of

Table 1. Distribution of sex among the participating participants.

		Frequency	Percent
Sex	**Male**	601	41.8
	Female	836	58.2
	Total	1437	100

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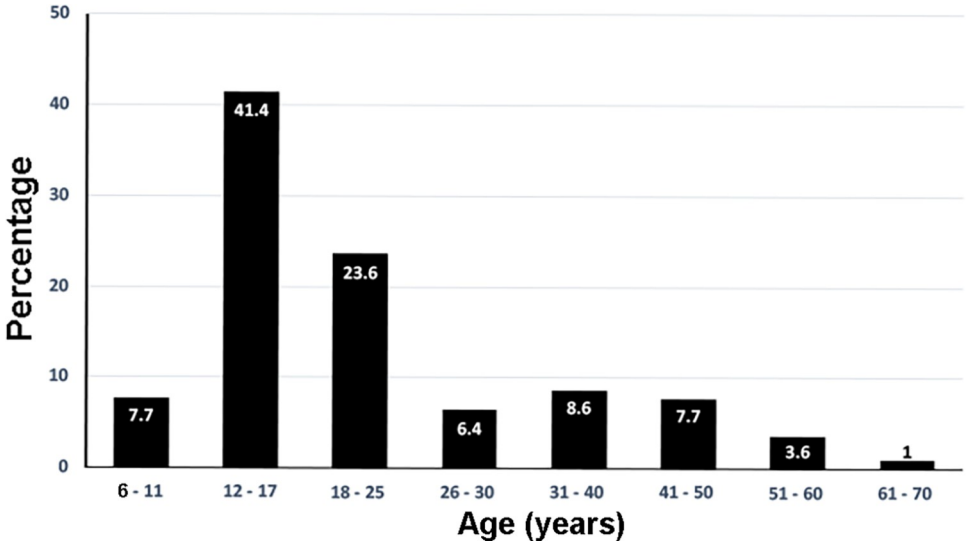

Fig 1. Distribution of ages of participating participants. The distribution of ages of participants is shown in Fig 1 as 65% of the participants were aged from 12–25 years old.

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Cook County and Chicago was statistically significant. The lag-zero correlation was 0.943, and the direction of the correlations was positive. However, the lag-zero cross-correlations positivity rates of Cook County or City of Chicago and the orthodontic clinic at UIC are very low as 0.212 and 0.240, respectively. Interestingly, the frequency of COVID-19 detection at the orthodontic clinic increased during the high positivity rate in Chicago and Cook County, IL (Fig 5). Note that Chicago posted an indoor mask mandate on August 26, 2021.

Discussion

This study is the first to report the positivity rate of SARS-CoV-2 infection in the orthodontic patient population. Positivity rate is a better indicator of the spread of the disease than the

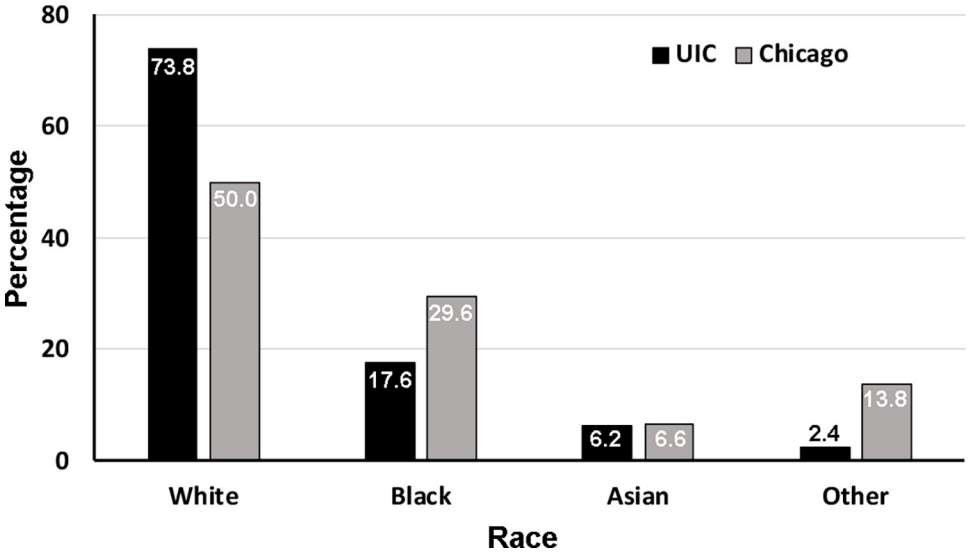

Fig 2. Comparison of the population by race between the patients at UIC orthodontic clinic and City of Chicago. The similar distribution of races between the orthodontic patients at UIC and the population of the City of Chicago was shown. The majority of the patients were white. Black bars: UIC; Gray bars: City of Chicago.

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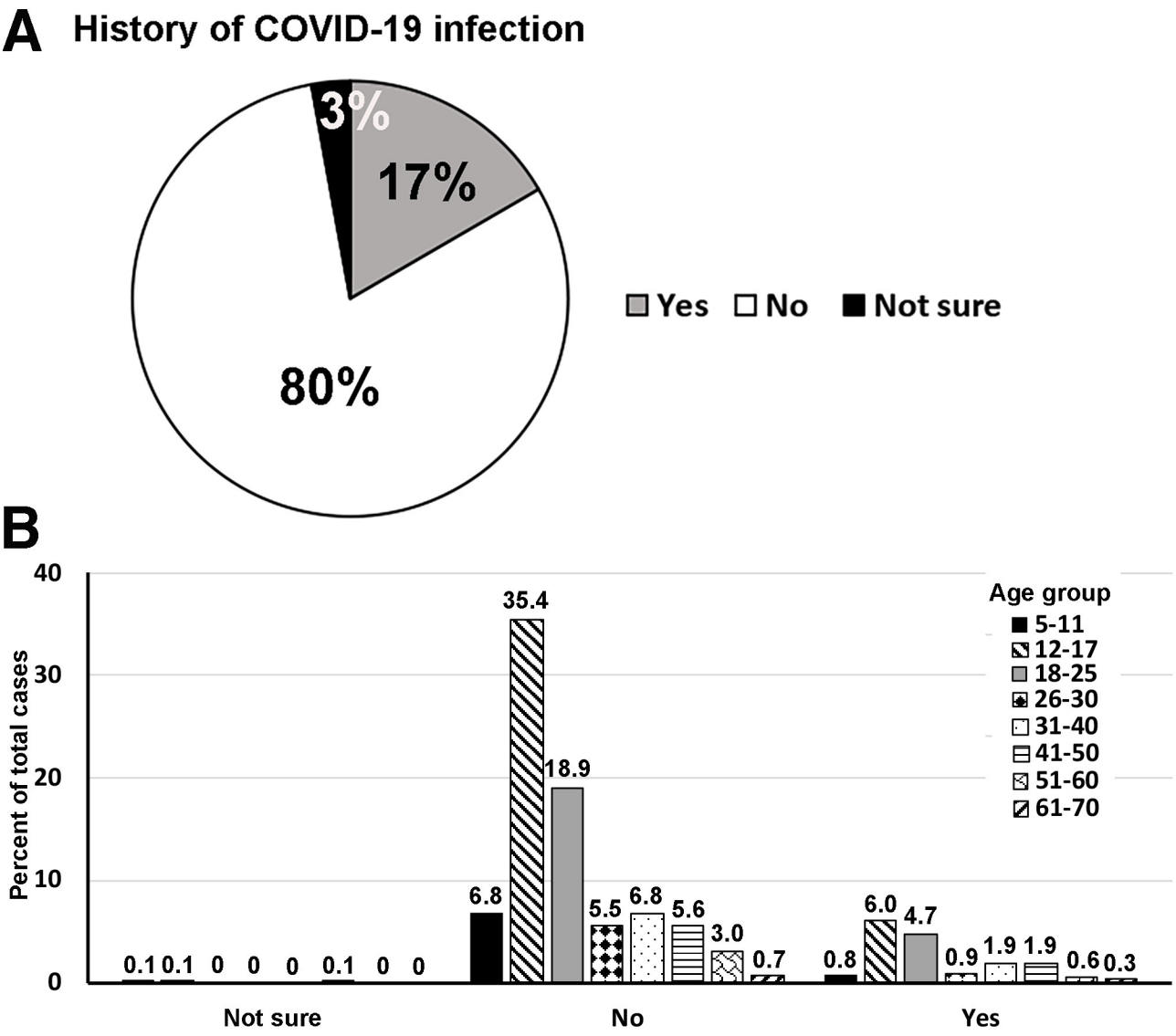

Fig 3. Distribution of participants by a history of COVID-19 infection. Most participants did not have COVID-19 infection, and only 17% of total participants had COVID-19 infection (A). The history of COVID-19 infection by age group was shown, and the group of 12–17 years old had the most number of participants with a history of COVID-19 infection (B).

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number of confirmed cases because it is calculated from the total numbers of the employed test [32]. High positivity rate could be contributed by the high number of positive tests or the low number of total tests. The age distribution of the participants in this study were similar to the orthodontic patients' age distribution in the United States from 1996 to 2016 [33], implicating increased numbers of the adult population. The distribution of races of the participants were similar to the distribution of races of the population in the city of Chicago as well [34]. Few reports showed that the positivity rates of SARS-CoV-2 infection in asymptomatic dental patients in Glasgow and Israel were 0.5% [35] and 0.027% [36], respectively. The positivity rate of SARS-CoV-2 infection in asymptomatic pediatric dental patients was reported as 2.3% [37] and the emergency dental department in Chicago was 6.7% [38]. However, all previously reported positivity rates were reported before the emergency usage authorization of COVID-19 vaccines [39]. Our study reported the positivity rate of SARS-CoV-2 infection in the

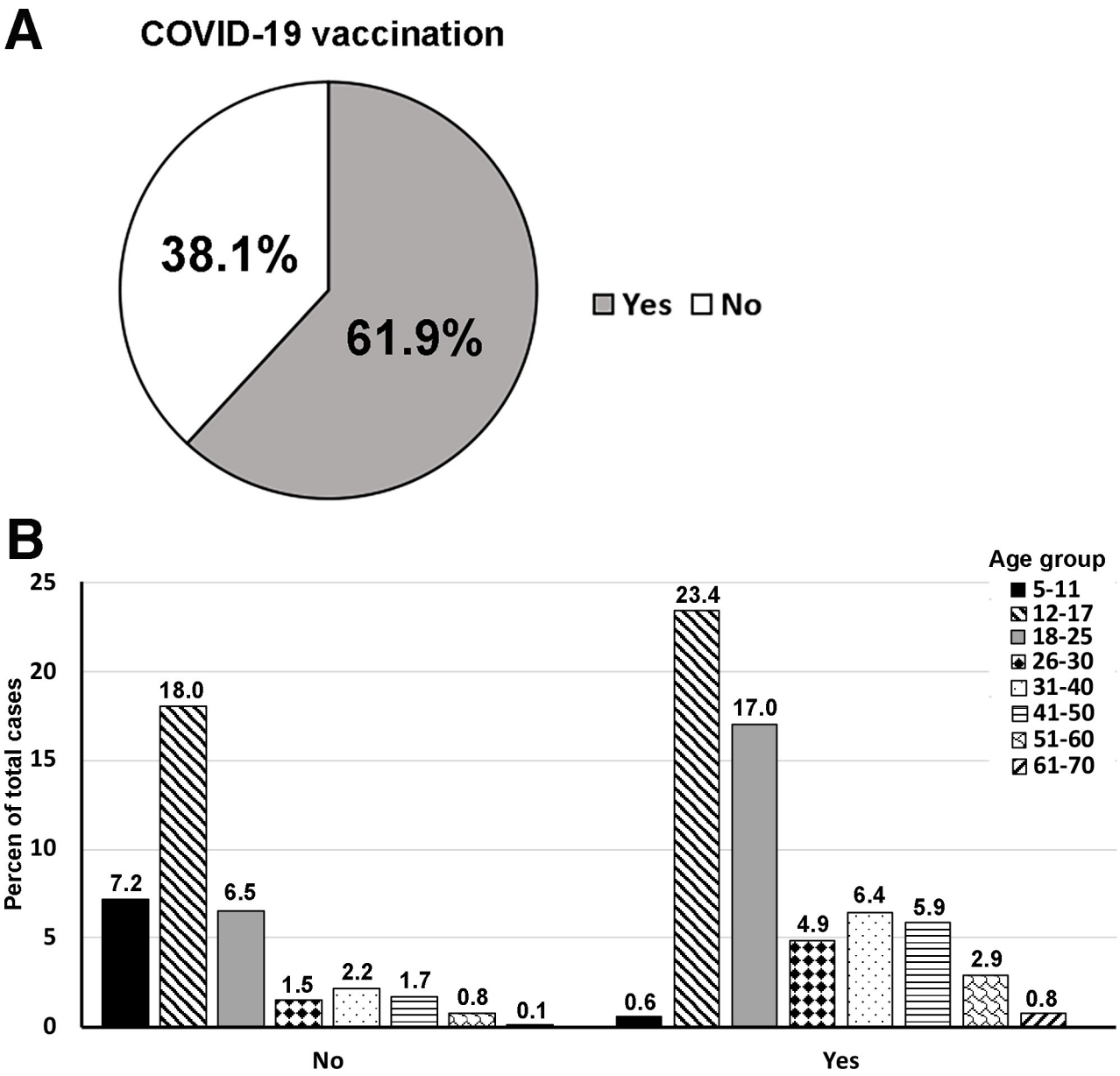

Fig 4. Distribution of participants by COVID-19 vaccination status. Approximately 62% of participants received full doses of COVID-19 vaccination (A). The vaccination status by age groups showed the highest number of the vaccinated group was aged 12–17 years old (B).

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orthodontic patient population after the COVID-19 vaccine distribution in the United States. This report represented the population with a contemporary background of COVID-19 vaccination and similar age distribution of orthodontic patients in the United States. The study utilized a highly sensitive and specific RT-qPCR test developed by the clinical diagnostic laboratory at the UIC Department of Pathology to detect SARS-CoV-2. The clinical diagnostic laboratory at the UIC Department of pathology is the Clinical Laboratory Improvement Amendments of 1988 (CLIA) and the College of American Pathologists (CAP)-accredited laboratory. During the study, the city of Chicago administered COVID-19 vaccination an average of 5,200 cases a day [40]. We collected the history of COVID-19 infection and COVID-19 vaccination status to investigate the possibility of reinfection and breakthrough infection. In this

Table 2. Details of the SAR-CoV-2 positive participants.

Participant	Sex	Age	Race	History of infection	COVID-19 Vaccination
1	F	11	white	no	no
2	M	10	black	no	no
3	F	31	white	no	no
4	M	26	white	yes	no
5	M	10	white	no	no
6	M	13	white	yes	yes
7	M	44	white	no	yes
8	F	17	black	no	no
9	M	17	black	no	yes

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study, most participants who received complete vaccination aged between 12–25 years old. No COVID-19 vaccine was authorized to be administered to children below 11 years old during the study period. In this study, two positive participants reported a history of COVID-19 infection, indicating their reinfection status without any symptoms. There were several case reports of COVID-19 reinfection in the literature [41–43]. Three positive participants reported a history of complete COVID-19 vaccination, indicating breakthrough infection. Literature reported COVID-19 breakthrough infection in many countries, including the United States [44–46]. In this study, we did not find a statistical correlation between the daily positivity rates of SARS-CoV-2 infection at the orthodontic clinic at the University of Illinois Chicago and the city of Chicago or Cook County, IL. It is possible that the low numbers of positive cases were detected in the orthodontic patient population due to the prescreening process before the appointments. This prescreening process was implemented at the orthodontic clinic following the guidelines issued by the US CDC to implement COVID-19 mitigation for dental procedures to prevent in-office transmission [47]. Another speculation is that only asymptomatic

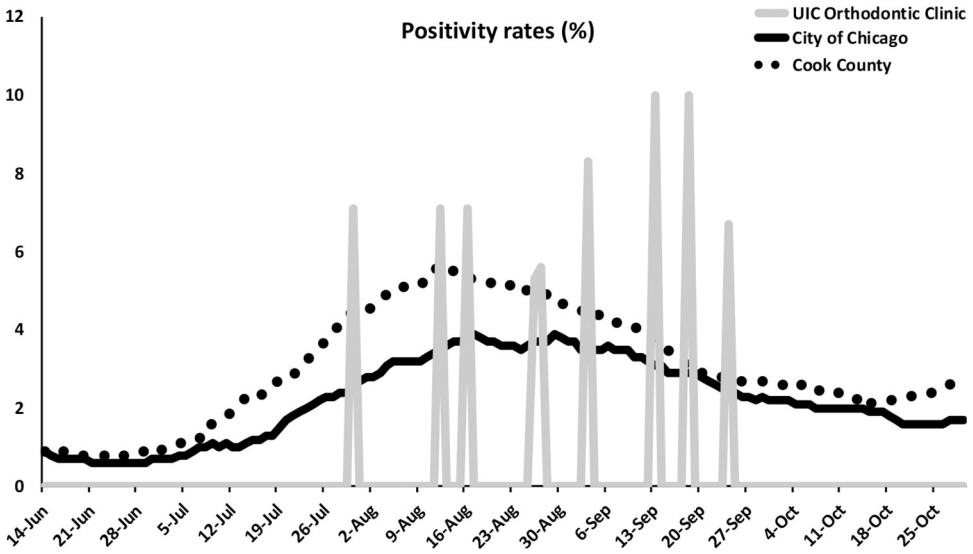

Fig 5. Correlations among the SARS-CoV-2 positivity rates of the orthodontic clinic, University of Illinois Chicago, Chicago and Cook County, Illinois. There was no correlation between the positivity of SARS-CoV-2 infection at the orthodontic clinic and the city of Chicago and Cook County, IL. There was a high correlation between the positivity rates of the City of Chicago and Cook County. The lag-zero correlation was 0.943, and the direction of the correlations was positive.

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patients sought orthodontic treatment, while the symptomatic patients would isolate themselves at home until they recovered and came back for their orthodontic appointments according to the guidelines of the US CDC. More than half of the participants had received the COVID-19 vaccines, which would affect the positivity rate of the orthodontic patients as well. The high positivity rate of Chicago and Cook County, IL were most likely obtained from the individuals who were tested when they likely had symptoms related to COVID-19.

We chose saliva as the specimen type for detecting SARS-CoV-2 in this study. The analytical sensitivity and specificity of viral detection in saliva has been reported to be equivalent or even better than NP swabs in many studies [18,48–51]. Saliva is very advantageous over NP swabs because it can be self-collected in a non-invasive manner and transported to the lab without any collection medium. Unlike NP swabs, there is no need for trained personnel to collect saliva, less painful and more subject-friendly. It is challenging to compare results from saliva and NP swabs directly because most RT-PCR tests that are performed on NP swabs are optimized to this specimen type only. Using the same test conditions for saliva may not be appropriate because unlike NP swabs, RNA extracts from saliva contain significant amounts of host cellular DNA, RNA and bacterial nucleic acids. Differences in the composition of the extracted nucleic acid may translate to differences in test performance if the test is not optimized and validated properly to detect SARS-CoV-2 in saliva. The test that we used in this study was appropriately validated in the clinical molecular pathology lab to detect SARS-CoV-2 in saliva. Saliva has also been reported to be positive for longer periods of time with higher viral loads when compared to NP swabs [52]. Overall current evidence suggests that after appropriate validation, saliva is an excellent specimen type to detect SARS-CoV2 with high sensitivity and specificity by RT-PCR tests.

Conclusion

The positivity rate of SARS-CoV-2 infection in patients who visited the orthodontic clinic at UIC was low compared to the positivity rate in the City of Chicago and Cook county. However, our study shows that the risk of transmission to providers exists even when the positivity rate is low from individuals who are asymptomatic and vaccinated yet infected. Testing for SARS-CoV-2 on the day of the appointment may help to reduce that risk. The absence of symptoms or illness cannot be relied upon to assess COVID-19 infection status. As such, universal precautions have to be followed to mitigate the risk of transmission to providers.

Supporting information

S1 Table. Data set of PCR result from individual subject with demographic data and history of SARS-CoV-2 infection and vaccination.
(XLSX)

S2 Table. Data set of positivity rate of the department of Orthodontics at UIC and the rates of Chicago and Cook county.
(XLSX)

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