Comparative evaluation among different materials to replace soft tissue in oral radiology studies

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ABSTRACT

Objective: The aim of this study was to establish which materials afford better simulation of soft tissues in Oral Radiology studies. Material and Methods: The sample was composed of four materials in eleven different thicknesses to simulate the soft tissues of the face. The mean values of the relative amounts of radiographic contrast of the materials were determined and compared to a gold standard value, which was obtained from 20 patients who were referred to have periapical radiographs taken of the left mandibular molars. Data were subjected to statistical analysis with Dunnett’s test (p<0.05). Results: The mean value of the relative amounts of contrast encountered in the patients was 0.47, with a range between 0.36 and 0.64 for all 44 material/thickness combinations. The majority of the tested materials showed values close to those of the patients’ tissues, without statistically significant differences among them. The values of only three materials/thickness combinations differed statistically from those of the patients’ tissues. Conclusions: Based on the results of the present study, it may be concluded that except for utility wax (4 mm and 8 mm) and water (4 mm), all materials tested at different thickness could be used as soft tissue substitute materials in Oral Radiology studies.

Key words: Tissues. Radiography dental. Simulate.

INTRODUCTION

In Oral Radiology research, phantoms are frequently used to simulate the patient’s body. There are, however, some requirements for tissue substitutes. A material that could be easily obtained and simulate the soft tissue would be helpful for Oral Radiology professors and researchers. It is important for these materials to be capable of being accurately measured, available, reproducible, and ready to be used in any instance⁶. Thus, standardization would be perfectly possible. The development of phantoms that present densities similar to those observed in patients is very important because it avoids unnecessary radiation exposure. According to the ALARA principle, all unnecessary exposure to radiation should be avoided¹⁵. The significant influence of the patient’s soft tissue located between the bone and the x-ray beam. The intensity of an x-ray beam is reduced by interaction with the matter it encounters. This attenuation results from interactions of individual photons in the beam with atoms in the absorber. The x-ray photons are either absorbed or scattered out of the beam¹⁵. It is expected that this phenomenon also occurs when the x-ray beam interacts with the mandible. It is thus very important to consider the presence of a specific material that simulates the soft tissue of the human face when obtaining the optical value of the jaw density³.

Various materials simulating soft tissues have been cited: water, wax, self-polymerizing resin, paraffin and polyethylene¹-³,5,9,13. However, all studies consider bovine muscle as gold standard located between the bone and the x-ray beam. The intensity of an x-ray beam is reduced by interaction with the matter it encounters. This attenuation results from interactions of individual photons in the beam with atoms in the absorber. The x-ray photons are either absorbed or scattered out of the beam¹⁵. It is expected that this phenomenon also occurs when the x-ray beam interacts with the mandible. It is thus very important to consider the presence of a specific material that simulates the soft tissue of the human face when obtaining the optical value of the jaw density³. Various materials simulating soft tissues have been cited: water, wax, self-polymerizing resin, paraffin and polyethylene¹-³,5,9,13. However, all studies consider bovine muscle as gold standard located between the bone and the x-ray beam. The intensity of an x-ray beam is reduced by interaction with the matter it encounters. This attenuation results from interactions of individual photons in the beam with atoms in the absorber. The x-ray photons are either absorbed or scattered out of the beam¹⁵. It is expected that this phenomenon also occurs when the x-ray beam interacts with the mandible. It is thus very important to consider the presence of a specific material that simulates the soft tissue of the human face when obtaining the optical value of the jaw density³.

A specific substitute tissue that presents contrast values similar to those of humans is essential
and might facilitate all radiological experiments and education. Thus, the aim of this study was to establish which materials offer better simulation of soft tissues in Oral Radiology studies, using the human soft tissue as gold standard.

MATERIAL AND METHODS

The sample was composed of four different materials in eleven different thickness (4, 8, 12, 15, 20, 24, 28, 32, 36, 40 and 45 mm): self-polymerizing acrylic resin, utility wax, wood and a 2 mm-thick polymethylmethacrylate box filled with a 2-mm-thick water layer. All materials were exposed using InSight dental film (Eastman Kodak Co., Rochester, NY, USA) with the addition of an aluminum step-wedge. Standardized conditions were used: GE 1000 machine (General Electric Co., Milwaukee, WI, USA), operating at 70 kVp, 10 mA, and 40 cm focus-film distance. The dental films were attached to a dry mandible, with buccal interposition of a soft tissue substitute material, and the x-ray beam was projected perpendicular to the film (Figure 1). Three standardized radiographs of each material at its specific thickness were obtained from the mandibular posterior segment of a cadaver.

Using a densitometer (MRA, Ribeirão Preto, SP, Brazil), it was possible to determine the radiographic density value of all materials at their specific thicknesses. This value was used to obtain the relative amounts of contrast or contrast index, according to Price\textsuperscript{12} (1986), using the following equation:

\[
C = \frac{D_2 - D_7}{0.5(D_2 + D_7)},
\]

where C is the relative amounts of contrast or contrast index, \(D_2\) and \(D_7\) are the second and seventh step of the density scale, respectively.

Radiographs from 20 patients referred to have periapical radiographs of mandibular left molars taken at the Oral Radiology Clinic of Piracicaba Dental School, State University of Campinas, were used. The research protocol was approved by the Research Ethics Committee of Piracicaba Dental School, and the patients signed an informed consent form before their enrollment.

All radiographs were taken in accordance with routine procedures. The patients wore lead aprons and leaded thyroid collars in order to enhance the diagnostic benefits of dental radiographs and minimize patient’s exposure to radiation. All images were exposed with the same GE 1000 machine, InSight dental film and focus-film distance. Using a densitometer, it was possible to determine the radiographic density value of each patient. This value was used to obtain the soft tissue relative amounts of contrast or contrast index, according to Price\textsuperscript{12} (1986), as mentioned above. The mean of these values was used as gold standard.

All films were processed using a Gendex GXP (Gendex Dental Systems, Lake Zurich, IL, USA) with fresh Kodak processing liquids and operating time of 5 min.

The mean values of the relative amounts of radiographic contrast of each material (at its specific thickness) were compared with the gold standard value using Dunnett’s statistical analysis (\(p<0.05\)).

Figure 1- Dental film fixed in a film holder attached to the posterior region of a dry mandible with buccal interposition of acrylic in order to simulate soft tissue.
RESULTS

The results showed that the mean value of the relative amounts of contrast encountered in the patients was 0.47, with a range between 0.36 and 0.64 for all 44 material/thickness combinations. The majority of the tested materials showed values close to those of the patients' tissues, without statistically significant differences among them. It was possible to observe that the values of only three materials/thickness combinations differed statistically from those of the patients' tissues, utility wax (4 and 8 mm), which presented mean relative amounts of contrast of 0.64, 0.63 and 0.62, respectively (Table 1).

When analyzing the four different materials at each specific thickness (4, 8, 12, 15, 20, 24, 28, 32, 36, 40, 45 mm), there was no statistically significant difference among them. However, when comparing one specific material at its eleven different thicknesses, there were statistically significant differences among some of the thicknesses (Table 1).

DISCUSSION

As it is impossible to measure doses within the patient, many tissue-equivalent materials have been developed, and dosimetric studies have been conducted in phantoms that approximate the human form to reflect the x-ray absorption and scattering properties of various tissues\(^4\). The materials at the specific thicknesses evaluated in the present study are ideally appropriate for radiographic, dosimetric and radiobiological studies.

Water was the first soft tissue substitute material to be used in radiation measures and up to now it continues to be tested\(^5\). Blake, et al.\(^1\) (1992) studied the effects of beam hardening on measurements made with a commercial dual energy x-ray scanner.
of the patient’s tissues: utility wax 4 mm and 8 mm, which presented mean relative amounts of contrast of 0.64 and 0.63, respectively.

Demann, et al.6 (2002) investigated the effects of soft tissue and position on vector during distraction. The authors used polyethylene straps in the temporomandibular joint region in a manner that resembled the origin and insertion of the masticatory muscles. They concluded that simulated soft tissues of the face affected the vector of distraction. Other materials, such as epoxy resin and hydrophilic materials, have also been used to substitute soft tissue in Oral Radiology7,14.

In this study, the materials were chosen according to their availability and reproducibility. The thicknesses of the materials were determined based on the reference values of the patients. Thus eleven different thicknesses were established for each material in order to find out the specific thicknesses that presented no statistical difference from those of the patients. The contrast values of the materials tested resemble human biological tissue.

Phantom materials are used to simulate the interactions of electromagnetic radiation with the body tissue and organs. A material that scatters and absorbs radiation in a similar way as that of the body is a potentially useful phantom material7. However, there are very few reports in the literature concerning materials used as soft tissue substitutes in Oral Radiology research. In this study, different possibilities of materials and thicknesses that can be used to replace soft tissues in Dentistry have been presented.

The clinical significance of the present work is related to the fact that the reference values were obtained from patients with different tissue densities. Therefore, the patient’s muscle used as gold standard was more precise and reliable.

CONCLUSION

It was possible to conclude that except for utility wax (4 mm and 8 mm) and water (4 mm), all materials tested at different thickness could be used to simulate soft tissues in Oral Radiology studies.

REFERENCES