



Fifty years of microscope use in scientific publications: the Dental Research Institute (Witwatersrand) experience (1954-2004)

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A study providing a historical and factual account of 50 years microscope-based dental research activity which will be of vital comparative importance in the forthcoming era of "microscopy taught digitally".

The Dental Research Institute (DRI) of the Medical Research Council/University of the Witwatersrand (1954-2004) has recently completed a retrospective audit of all published, peer reviewed research papers (total 625) that appeared in the 50 years of its existence (Grossman, Mogotsi & Cleaton-Jones, in press). A notable feature of the analysis was the many studies that used microscopy in their methodology. However, striking changes have taken place within this research arena in the recent past that could impact on future microscope use as a research tool within dentistry, not only at the University of the Witwatersrand, but globally. Wide-ranging advances in imaging and image quality, expanding avenues of associated technology and increasing sophistication of quantitative software have revolutionised the scope of traditional microscopy. Coupled with this, the teaching program of health-based sciences has seen "digital microscopes" replacing traditional optical microscope instruction methods in pertinent subjects (Cotter, 2001). Finally, there is an initiative, supported by a major dental research-funding agency, to move the research agenda towards a "practitioner based" approach. This is to obtain "real world" data that are clinically relevant rather than the current emphasis of "basic scientists testing theoretical problems and hypotheses" (Mjör, 2005). In the light of these changing paradigms and burgeoning developments, a record of past use of microscopes in a typical dental research entity is timely for future reference. The DRI database is well suited to provide such a historical record.

The history of the DRI has previously been published (Cleaton-Jones & Grossman, 2004) but in brief, it is a small research entity within the School of Oral Health Sciences at the University of the Witwatersrand (Wits), Johannesburg, South Africa. A joint venture between Wits and the Council for Scientific and Industrial Research established the DRI in 1954 with staff consisting of a director and one technician. For a short while in the late 1970's it carried a complement of eight researchers and technical staff. At closure (2006) staff is back to one director and a senior researcher. DRI activities involve research in a variety of disciplines, teaching of research methodology and research supervision. In the latter case, 110 higher degrees (Masters and PhD's) have been successfully obtained through the DRI.

- The aim of this article is to record microscope use over the fifty years of DRI activity using published scientific papers as the data source to establish:
- Types of microscopes used
 - Role of the microscope in the study design
 - Quantitation of data
 - Research field
 - Author details
 - Journal of publication

Methods and Materials

The creation of the DRI database together with the classification and breakdown of DRI research outputs has been described (Grossman, Mogotsi & Cleaton-Jones, in press) and will not be detailed here. In brief, a copy of each DRI peer-reviewed paper was obtained, scrutinised and flagged for

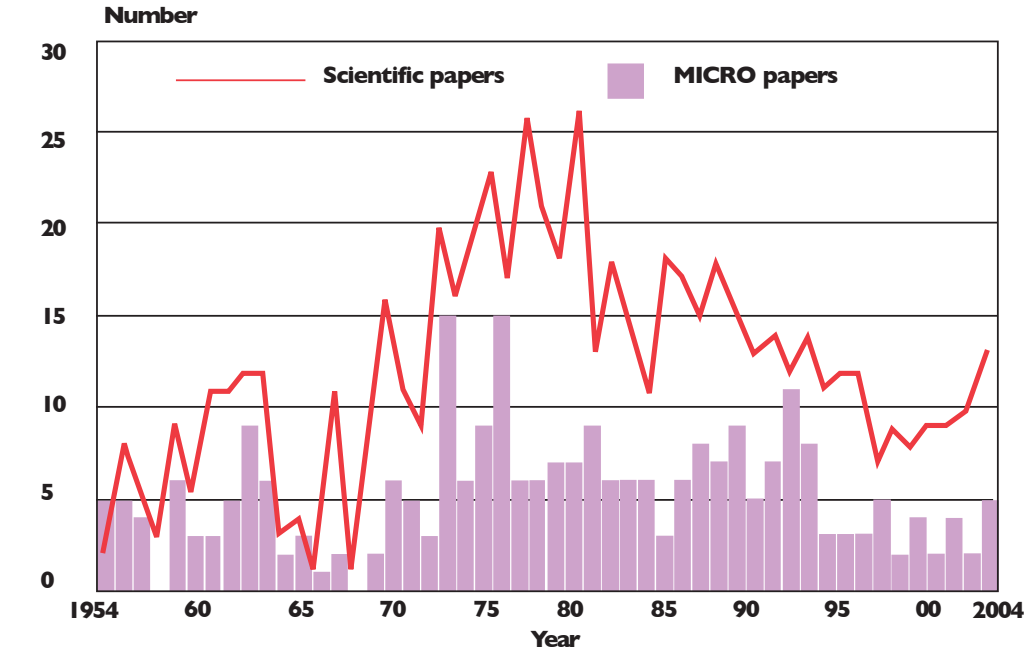


Fig. 1. The solid line indicates the total number of scientific papers produced by the DRI between 1954-2004. The bars indicate the number of papers which included microscope use.

identifiers. The coded information was evaluated using SAS for Windows (Version 9.1, SAS Institute Inc., Cary, NC: USA). The present study deals only with published, peer-reviewed research papers that used some form of microscopy in the study. Data, previously published, will be referred to, only to clarify and contextualise findings.

Results

The data is summarised in Tables 1-2 and Figures 1-4. Six hundred and twenty five DRI scientific papers were published between 1954-2004, of which 263 (42%) utilised microscopes (MICRO) in some way (Figure 1). Table 1 shows the trend of microscope use over the five decades of the study, indicating that usage has dropped over the years. Overall, microscopes were the major or sole research tool in 80% of the papers, played a minor role in 2% of studies and a co-role in 18% of the papers (Figure 2). These proportions have changed little over the five decades. Co-role studies were indicated where two research tools were equally used: for instance a profilometer and scanning electron microscope (SEM) in surface roughness studies of dental

materials (Retief, 1974). Minor microscope use was typically indicated when the microscope was used to corroborate a finding or calibrate a procedure, but produced results which were of lesser concern to the outcome of the study (Friedman et. al., 1976). The figure of 2% prevalence for minor microscope roles could be underreporting: scrutiny of the 625 papers indicated that some

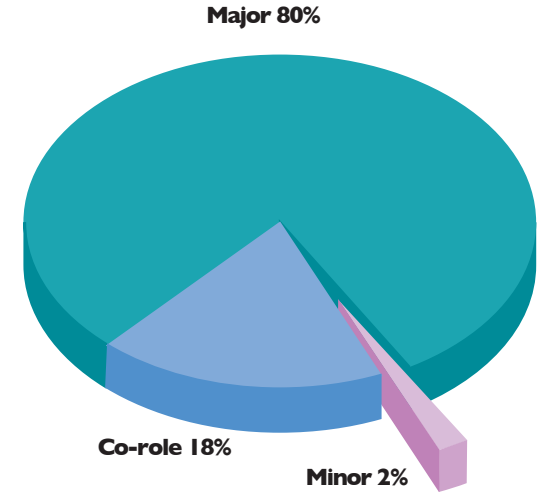


Fig. 2. Pie chart showing the role of the microscope sourced data in the 263 research papers.

Time period					
Category	1954-1964	1965-1974	1975-1984	1985-1994	1995-2004
Number of papers	45	43	76	67	32
% of total DRI papers/ decade	54%	44%	39%	45%	31%
*Top five authors	jti; xms; ahm; cjd; agp = 86%	dhr; pcj; cjd; jca; cfv = 60%	jca; pcj; esg; dhr; egv = 58%	ugo; esg; pcj; jca; are = 44%	esg; pcj; jmt; rqp; mjw = 56%
Top 3 journals / proceedings	Nature; S Afr J Med Sci; SADJ = 44%	SADJ; S Afr J Med Sci; J Periodontal Res = 49%	SADJ; Proc Microsc Soc South Afr; J Dent Res = 42%	Proc Microsc Soc South Afr; J Prosthetic Dent; Endo Dental Traumatol = 30%	Proc Microsc Soc South Afr; SADJ; J Prosthetic Dent = 61%
Microscope type	Light=100%	Light=70%; mixed =16%; SEM = 14%	Light=46%; SEM = 29%; mixed = 16%; TEM = 9%	Light=67%; SEM = 19%; mixed = 11%; TEM = 3%	Light=45%; SEM = 36%; mixed =19%
Microscope involvement	Major=87%; co-role=11%; minor=2%	Major=65%; co-role=30%; minor=5%	Major=81%; co-role=16%; minor=3%	Major=81%; co-role=19%	Major=84%; co-role=16%
Field of investigation	Basic research; clinical; physical; histology; pathology = 59%	Basic research; dental materials; bone; oral soft tissue; clinical = 52%	Dental materials; oral soft tissue; histology; pulp; restoration = 66%	Bone; growth & development; dental materials; histology; restoration = 60%	Dental materials; restoration; caries; pulp; treatment = 81%
Quantitation	None=67%; arithmetic=31%; inappropriate=2%	None=60%; arithmetic=12%; stats = 19%; inappropriate=9%	None=26%; arithmetic=8%; stats = 61%; inappropriate=5%	None=24%; arithmetic=8%; stats = 67%; inappropriate=1%	None=16%; arithmetic=3%; stats = 81%;
Study design	Descriptive=56%; experiment=44%	Descriptive=67%; experiment=26%; review=7%	Experiment=55%; descriptive=42%; review=3%;	Experiment=61%; descriptive=37%; review=2%;	Experiment=81%; descriptive=19%;

Table 1. Details of the 263 MICRO research papers 1954-2004 broken down into decades featuring paper content, journal and author particulars. Percentages which are given are for the decade. (*Each three-letter abbreviation indicates an individual author.)

research must logically have used a microscope to facilitate the investigation, but as this was not mentioned in the paper, it was lost for recording.

Microscope type

Light microscopy dominates type use (Figure 3). Mixed use occurred when more than one microscope was used in the study, such as light and scanning electron microscopy (SEM). SEM was first used in 1970 (Retief, Dreyer & Gavron, 1970), while the first TEM MICRO appeared in 1976 (Cleaton-Jones, 1976). Increased use of supportive instrumentation (EDAX, backscatter, elemental mapping, fluorescence, low vacuum and environmental microscopy) has occurred as technology became available. No publications have arisen from work using the confocal, atomic force or Raman microscope although the methodology was piloted in planned studies which fell through for one or other reason. In the case of AFM the work was in an advanced stage when it came to an end as a

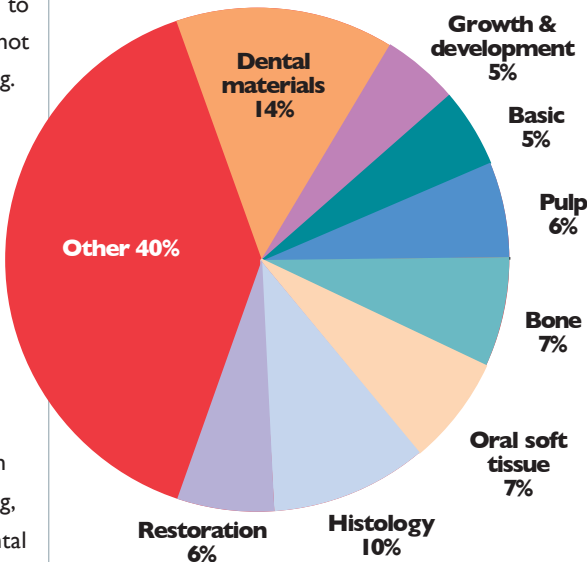


Fig. 4. Dental materials at 14% dominates the research field as microscope-based topics. However the 40% of “other” topics indicates the wide range of subjects researched at the DRI using microscopes.

result of the death of the principle investigator. Transmission electron microscopy (TEM) use has vanished from the research agenda in the last decade of study.

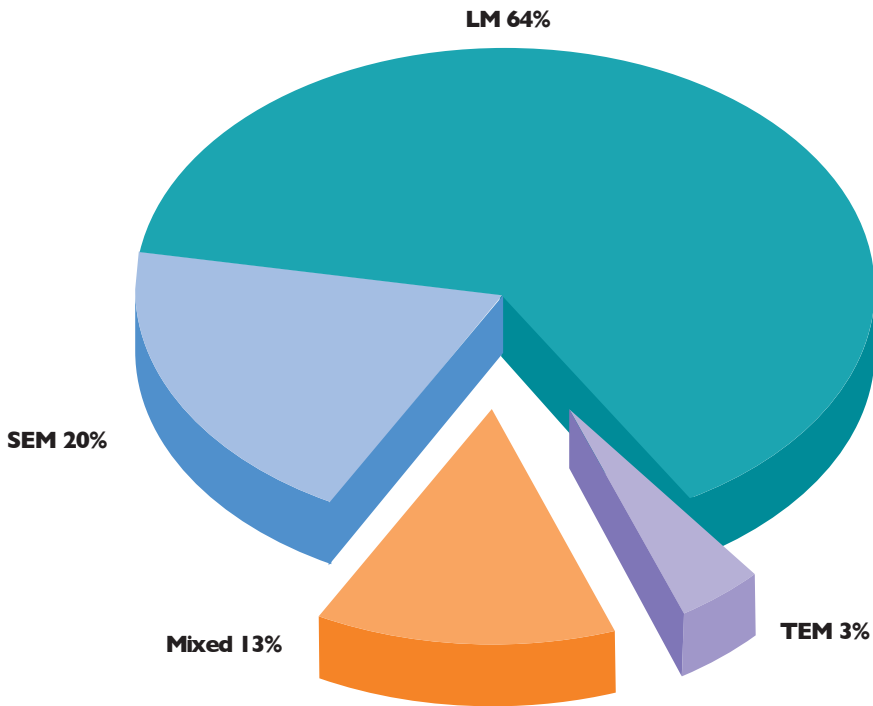


Fig. 3. Pie chart showing the proportional use of microscopes in the 263 papers. Light microscopy dominates as a microscope type.

Research topic

The DRI has investigated all conceivable topics with microscopes (Figure 4). The top five fields of investigation, by decade, are in Table 1 together with their percentage occurrence. These have varied over the years as MICRO projects have changed in focus, but studies on dental materials have been popular for the past 40 years.

Study design

The trend over time is towards increasing scientific rigour of MICRO studies (Table 1). Study design has moved from mainly descriptive reports (56%) to experimental (81%) over the 50 years. Descriptive studies remain a sizable portion of output - 19% for the last decade.

Quantitation

The first paper to report any form of quantitation appeared in 1955 and used a micrometer eye-piece to measure fundic bone width. While quantitation took place, the approach was not systematic, with neither specimen numbers nor numbers of measurement fields or sizes reported (Baillie &

Irving, 1955). Data reporting has moved away from studies with no form of quantitation (67%) in the first decade of this report, towards statistical testing of data (81%) in 1995-2004. Arithmetic listing of results, without statistical analysis, has formed less than 10% of all studies for the past 30 years.

Journals and Proceedings

Journals publishing MICRO papers are mainly the South African Dental Journal and the Proceedings of the Microscopy Society of Southern Africa with a fair spread of international dental journals (Table 1). Journals published outside South Africa's borders account for 64% of all MICRO publications.

Authors

One hundred and thirty individuals contributed to MICRO papers. Sixty four individuals co-authored more than one paper, amounting to 609 authors for 263 MICRO papers, averaging 2.3 authors per paper. Authors were mainly staff of the DRI (57%); private practitioners and collaborators from the

Top ten MICRO authors*	Number of MICRO papers (% of 263)	Papers % of 609 authors	Author's total contribution to DRI papers (n=625)
Author 1 - pcj	80 (30.5%)	13.2%	307
Author 2 - esg	61 (23.2%)	10.0%	72
Author 3 - jca	50 (19.0%)	8.2%	74
Author 4 - dhr	28 (10.6%)	4.6%	65
Author 5 - ugo	26 (9.9%)	4.2%	31
Author 6 - jti	23 (8.7%)	3.8%	32
Author 7 - jmt	15 (5.7%)	2.4%	25
Author 8 - xms	15 (5.7%)	2.4%	15
Author 9 - cjd	14 (5.3%)	2.3%	41
Author 10 - lpf	13 (4.9%)	2.1%	47

Table 2. Publication output of the 10 most productive MICRO authors (total = 130) listed in the 263 MICRO research papers. The last column indicates the total number of papers (MICRO and non-MICRO) produced by each individual as a DRI researcher. (*Each three-letter abbreviation indicates an individual author.)

Wits School of Oral Health Sciences (18%) or other academics, mainly non-health professionals (18%). Thirty-four percent of MICRO authors were undergraduate or postgraduate students, having completed an undergraduate research project or post-graduate degree with the DRI. Many DRI staff, private practitioners and collaborators are in this group, thereby sharing a dual relationship with the DRI. Eighty-one MICRO papers were derived from work covered by theses for higher degrees and diplomas.

The top ten MICRO authors are listed in Table 2 together with the number of papers they have contributed towards, their percentage of the 609 authors, and finally the total number of DRI papers they have co-authored. The top ten authors contributed individually or jointly to 239 of the 263 MICRO papers. The inevitable double counting of some MICRO papers resulting from this co-authoring is the reason for the overall percentage in the first column being over 100%. The final column gives an indication of the distribution of MICRO papers compared to overall DRI research topic output. Author 1, a general researcher, has a total of 307 DRI papers of which 80 are MICRO papers – thus 26% of his research output used a microscope. This should be contrasted with Author 8, an oral pathologist, who has produced a total of 15 DRI papers, all of which used microscopes. Research productivity (as indicated by number of publications) depends on length of association with the DRI (Author 1, 2 and 3) and seniority of position as is reflected by the four directors in position 1, 4, 6 and 9. Of note is the tenth most productive MICRO author, a career statistician, and definitely not a microscopist, whose prominent position in the ranking is indicative of the role he has played as consultant in the planning and statistical analysis of microscope based scientific studies.

Discussion

The 50-year DRI database has shown that the microscope is a well suited research instrument for the clinically trained dental researcher, with a wide range of microscopes and associated imaging techniques used in a variety of research fields. In keeping with global research trends, DRI microscope-based research has increased its scientific rigour by improved study design and statistical testing of data. The research has been extensively published, both locally and abroad in a wide variety of journals. Indubitably the DRI has attained its' level of microscope based research over the past half century because all four directors have been microscope enthusiasts. Microscope based research requires such champions to encourage its use, keep abreast of developments in the imaging field, understand the applications and to recognise its potential in solving dentally oriented research problems. Indeed, DRI microscope based projects have been selected using these four foundation principles. In the case of experienced researchers, microscopy as a research tool is a self-made choice; where under-or post-graduates are involved, this has required a careful matching of candidates and projects. Candidate factors include experience, interests and skills. Project factors depend on research material, the availability and suitability of the research topic and time factors in which to complete the project satisfactorily. Thus, every endeavor should be made to encourage microscope use and develop enthusiastic research leaders from Health Sciences Faculties to ensure the future use of microscopy as a research tool.

It is our perception that students given an electron microscope based project appear to gain more insight into the scientific process than is usual. At our University, electron microscopy requires students to work in a central facility staffed by life

sciences and materials trained personnel. Common laboratories are available to prepare and mount specimens and the microscopes are centrally used. Under- and post-graduate dental students doing research at the Wits electron microscope unit come into contact and interact with other students from wide-ranging research fields, with often better research backgrounds. Such exposure broadens research horizons and supplements knowledge of basic research ethos, creating an enriched research student.

Why has it become important to record microscope-based research in a clinical discipline such as dentistry at this point in time? On the one hand, the remarkable advances in the field of imaging and associated technologies will undoubtedly continue to be used by dental researchers the world over, to investigate future research questions in dental health. The introduction of computer-based instruction in the health sciences has had far-reaching positive effects on financial outlay, space allocation, staffing provision and instruction time in microscope based subjects such as histology and pathology (McLean, 2000). Ultimately, patients will benefit from this approach as echoed by Thomas Carey (2002), chair of the University of Michigan School of Dentistry's Department of Oral Medicine, Pathology and Oncology. "In short, computer-

based education ... is helping our students feel even more confident and better prepared for what they will experience outside the walls of the School of Dentistry after they graduate". On the other hand, detractors of digital microscopy mourn the loss of intuitive learning and scientific understanding which comes with microscope work. Skills such as methodical examination, interpretation, variability, "reading" a microscope slide and detailed observation are some of the proficiencies which will be lost (Cotter, 2001). Students are presented with superb digital microscope images and a structure which guides students in the study of these images with no understanding of how these images were obtained in the first place. Paradoxically, it is those very advances permitting the benefits of "digital" microscope teaching which have taken the ordinary microscope out of the laboratory into a specialised facility and effectively denied undergraduates a basic research instrument experience. In doing so, we have perhaps alienated future generations of potential dental researchers to microscope use. Together with the current emphasis on clinically based research, and the perception that medical and dental students are unconvinced that microscope skills are important for the general practitioner (Richards et al., 2000), we run the risk of losing future generations of dental clinicians from microscope based research.

Conclusion

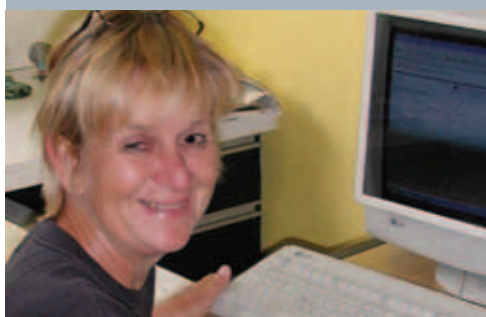
All 263 peer-viewed, published research papers which used microscopes in their methodology were extracted from the 50-year Dental Research Institute database and examined. The results showed a drop in microscope use over the 50 years, microscopes were the major research tool in 80% of studies, the light microscope predominated (64%) and topics came from many research fields. Increased scientific rigour was evidenced by greater statistical testing of data and improved study design. Publishing journals were mainly from outside South Africa (64%) and authors were largely Dental Research Institute staff (57%). The study provides a historical record of microscope-based research in a dental research entity, which will be of vital comparative importance in the forthcoming era of "digital microscopy".

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Elly Grossman is a life scientist who has been working in the field of dental research for 27 years. She has kept a foot firmly in both camps over these years and in her publications and presentations she has tried to educate the scientist about dentistry and the dentist about science, using the electron microscope as an aid. She is presently a Professor at the Dental Research Institute, University of the Witwatersrand, Johannesburg.

Mirriam Mogotsi



Mirriam Mogotsi has been working for the SA Medical Research Council since 1982 as a Research Technologist. During her time at the Dental Research Institute she was extensively involved in nutrition studies, scanning electron microscopy of tooth brush bristles and data capture. She was transferred to the MRC Health and Development Research Group in 2004 and is extensively involved in a number of studies related to domestic and industrial pollutants.